IT CORPORATION

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Volume I

Final Report
Further Action Area B
Treatability Tests

Wright-Patterson Air Force Base
Groundwater Basewide
Monitoring Program

Wright-Patterson Air Force Base
88th Air Base Wing
Office of Environmental Management

Environmental Management
Wright-Patterson AFB

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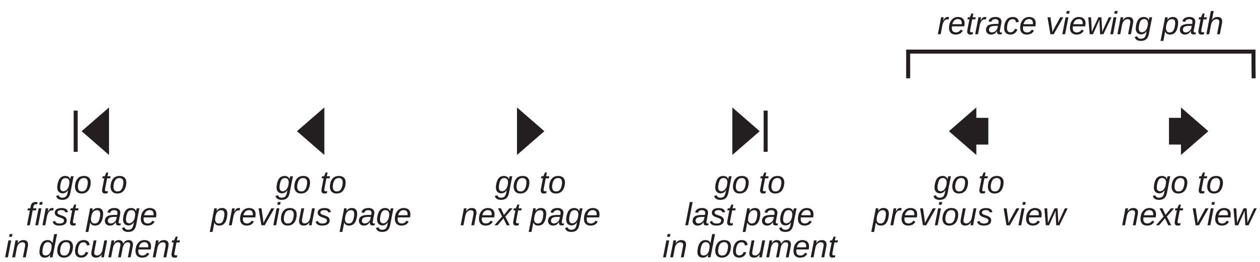

FINAL

REPORT ON
TREATABILITY STUDIES CONDUCTED
AT
FURTHER ACTION AREA B (FAA-B)

Volume I

Submitted to:
Wright-Patterson Air Force Base
88th Air Base Wing
Office of Environmental Management
Wright-Patterson Air Force Base, Ohio

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1.0 Introduction

This document presents the findings of the baseline characterization and treatability studies conducted for Further Action Area (FAA-B), located in Area B, Wright-Patterson Air Force Base (WPAFB), Ohio (Figure 1-1). The procedures for the baseline characterization and the treatability studies are presented in the document entitled *Final Work Plan, Treatability Studies at Further Action Area A and Further Action Area B (IT, 1999)*. Variations from the work plan are listed in Appendix A of this document. The baseline characterization and the treatability studies were initiated through the Installation Restoration Program (IRP) in accordance with the Administrative Orders on Consent (AOC) issued to WPAFB from the Ohio Environmental Protection Agency (OEPA).

1.1 Project Objectives and Scope

The objectives of the project were to 1) identify the source area of contamination, and 2) test the effectiveness of three in-situ remedial techniques for remediation of the contamination found in the subsurface of FAA-B. The following scope was developed to attain these objectives:

- Baseline Characterization – A series of soil and groundwater samples were collected and analyzed for the presence of volatile organic compounds (VOCs) to define the subsurface conditions and the contaminant distribution. These data are also used to locate treatment zones for in-situ chemical oxidation tests.

- Fenton's Chemistry Treatability Test – Injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) into the subsurface for the destruction of chlorinated hydrocarbons by chemical oxidation.

- Potassium Permanganate Treatability test – Injection of potassium permanganate into the subsurface for the destruction of chlorinated hydrocarbons by chemical oxidation.

- Hydrogen Injection Test – A "push-pull" test for measuring the anaerobic degradation rate of chlorinated hydrocarbons present in groundwater, using hydrogen as the electron donor for the degradation reaction.

1.2 Site Description and History

FAA-B is located in Area B (Figure 1-2) between 10th and 11th Street, just west of Skyline Drive in the vicinity of Facility 92, a drum storage area at WPAFB (Figure 1-3). This area, originally identified as SP11, was investigated in 1996 during the Basewide Monitoring Program (BMP) field activities to fill critical data gaps. Vinyl chloride in groundwater was detected in an upgradient well associated with an operable unit adjacent to the facility. Results of the BMP investigation are presented in the *BMP Field Activities Technical Memorandum* (IT, 1996b). The BMP investigation of FAA-B showed vinyl chloride to be present in groundwater above the maximum contaminant level (MCL), with a maximum detected concentration of 200 μg/L. The plume was estimated to be approximately 400 ft long by 200 ft wide and extend from the water table to near the bedrock surface at a depth of approximately 33 ft.

The subsurface materials encountered during the BMP investigation of FAA-B were typically silt and clay with lenses of sand. The depth to bedrock in FAA-B ranges from approximately 10 ft along the eastern portion of the area to 35 ft in the southwest portion of the area.

Subsequent to the BMP field activities an Engineering Evaluation/Cost Analysis (EE/CA) was prepared, assessing residual contamination against basewide remediation goals. FAA-B was identified in the *Engineering Evaluation/Cost Analysis, Basewide Monitoring Program (BMP EE/CA)*, (IT 1999) as an area where the current controls in place were insufficient to meet remediation goals. The preferred removal action recommended for FAA-B was chemical oxidation of residual contamination, if pilot tests show the method to be effective.

1.3 Report Organization

This report is organized as follows:

- Section 1.0 – Introduction. Describes the purpose of the report, presents a brief site description and history, and summarizes the results of previous investigations.

- Section 2.0 – Baseline Characterization and Well Installation. Describes the activities associated with the baseline characterization effort and for installation of the wells necessary for the treatability tests.

- Section 3.0 – Fenton's Chemistry Treatability Test. Describes the execution of this treatability test, including methods, total quantities of reagent injected, and monitoring results.

- Section 4.0 – Potassium Permanganate Treatability Test. Describes the execution of this treatability test, including methods, total quantities of reagent injected, and monitoring results.

- Section 5.0 – Hydrogen Injection Test. Describes the execution of this treatability test, including methods, total quantities of reagent injected, and monitoring results.

- Section 6.0 – Summary and Conclusions. Provides a summary of activities, significant conclusions, and outlines possible future activities.

2.0 Baseline Characterization

The baseline characterization was performed to better define the nature and extent of contamination. The goal of the baseline characterization – consisting of collecting soil and groundwater samples from a series of direct-push borings advanced in FAA-B – was to identify the source area of vinyl chloride contamination in groundwater (the area of highest concentration was to be targeted during the Fenton's Reagent injection test). Therefore the focus of the investigation was the two identified sand intervals present between the ground surface and the weathered bedrock (approximately 35 feet bgs). Investigations completed to date showed the presence two water bearing sand layers and the presence of vinyl chloride in groundwater. The extent of vinyl chloride contamination was not clearly defined, nor was a source identified. The baseline characterization was also intended to provide the necessary data to locate three monitoring wells that would be used to monitor the results of the treatability tests and future groundwater quality at this site.

2.1 Baseline Characterization Field Activities

The baseline characterization was started with initial soil borings in the vicinity of MW03 which had the highest vinyl chloride concentrations detected in FAA-B. Samples were analyzed at an on-site laboratory (see Section 2.1.3), with the results used to select subsequent sampling locations. A total of 19 soil borings were advanced, with soil and groundwater samples collected from each location. Following the soil borings, 3 monitoring wells were also installed. Figure 2-1 shows the locations of the soil borings and the monitoring wells. Boring logs are provided in Appendix B.

Field procedures for sample collection followed the procedures contained in *Project Work Plan for Remedial Investigations and Feasibility Studies at Wright-Patterson Air Force Base, Ohio*, dated 1990, (RI Work Plan) and were incorporated by reference in the project Work Plan. Laboratory methods and method detection limits for analytical methods are provided in Section

3.0 and 4.0 of the Work Plan. Data Quality Objective summary forms are presented in Appendix A of the Work Plan.

2.1.1 Soil Borings and Sampling

Each soil boring was advanced to the second sand lens or, if the second sand lens was not encountered, to bedrock (generally 35 ft below ground surface [bgs]) using direct push type sampling equipment and logged by a geologist for lithologic description. Soil samples were collected from the ground surface and from each successive 4-ft depth interval until the second sand layer or bedrock was encountered. These samples were screened at the drilling location with a portable photoionization detector (PID) and the two samples from each boring location registering the highest PID readings were submitted to the mobile laboratory for analysis. If no PID reading was registered, the soil sample collected from just above the water-bearing zone was submitted to the laboratory for analysis.

After completion of the most of the treatability studies, one additional boring was advanced to bedrock in the vicinity of MW-7 to determine if contamination had migrated to bedrock. This area was identified during the initial investigation, as the area with the highest concentration of VOCs in groundwater and soil. A sample was collected at the soil bedrock interface and submitted to a contract laboratory for VOC.

2.1.2 Groundwater Sampling

When a water-bearing zone was encountered, a microscreen with a sampling tube attached was advanced to the target depth to allow collection of a groundwater sample. Once the desired depth was achieved, the tool was retracted, exposing the microscreen to the water bearing formation. Samples were then collected using a peristaltic pump.

The screen and tubing were purged of three volumes prior to sample collection. The samples were collected into 40-mL vials with teflon-sealed lids, placed in a cooler, and submitted to the mobile laboratory for VOC analysis. Field parameters (pH, conductivity, and temperature) were measured for each of the samples collected. When more than one water-bearing zone was encountered, samples from each such zone were collected.

2.1.3 Sample Analyses

Soil and groundwater samples were submitted to an on-site mobile laboratory for analysis for the presence of volatile organic compounds (VOCs), using U.S. EPA Method 8260. The mobile laboratory was on-site from the beginning of the baseline investigation, through completion of the Fenton's Reagent injection (28-Sep-99 to 29-Oct-99). For quality assurance two groundwater samples and four soil samples were split and the splits submitted to an off site laboratory for analysis by U.S. EPA Method 8260.

2.1.4 Monitoring Well Installation and Sampling

During the baseline characterization, three monitoring wells (SP11-MW07, SP11-MW08, and SP11-MW09) were installed at the locations shown on Figure 2-1. The wells were located to target the areas of highest VOC concentrations and for purposes of monitoring the effects of the chemical injection. Drilling was conducted using hollow stem auger (HSA) drilling procedures. Soil in advance of each boring was sampled using a brass-tube lined split-spoon sampler to provide a continuous lithologic profile. Soil samples were collected during well installation at 4-ft intervals and groundwater samples were collected from water-yielding zones. Soil samples used for potassium permanganate bench scale studies (see Section 3.4) were also collected at this time.

Soil samples were collected by driving and retrieving a split-barrel sampler lined with four 6-inch long brass sleeves. The lower-most sleeve in the sampler was capped with polytetrafluoroethylene (PTFE) tape and plastic end caps for PID screening. Each soil sample was screened at the drilling location with a PID and the two soil samples from each boring location registering the highest PID readings were submitted to the mobile laboratory for VOC analysis. For MW07 the PID was out of service, therefore no PID readings are available for this well.

Monitoring wells were constructed of 2-inch-diameter stainless-steel screen and black iron risers, using 10 ft of well screen (0.010-inch slot size). All well construction materials were decontaminated prior to use. Stainless steel and black iron were used to protect against the expected heat generated from the Fenton's Chemistry injection process. The auger was advanced to just below the upper water-bearing strata, which was shown during this investigation as containing the highest levels of VOCs in groundwater. Boring logs and well completion logs are included in Appendix B.

The wells were completed by a sand pack that extended up to 6 inches above the top of the screen. Bentonite chips were placed above the sand pack up to within 2 ft of the ground surface. The balance of the annulus was filled with a cement bentonite grout. Each well was flush-mounted, and protected using a lockable cap and a steel well cover. A concrete pad was installed around each protective cover, sloped away from the cover to minimize rainwater from entering the cover.

Following construction, each well was developed with development considered to be complete when field parameters stabilized and turbidity was less than 25 nephelometric turbidity units (NTU). All sampling locations were permanently marked with a brass monument and the position and elevation of each sample location were surveyed. Table 2-1 lists the wells with state plane coordinates and top of casing elevations.

Following well development, groundwater samples were collected from the three new (SP11-MW07, SP11-MW08, and SP11-MW09) and five existing monitoring wells (SP11-MW01, SP11-MW02, SP11-MW03, SP11-MW04, and SP11-MW05). Monitoring wells were purged of stagnant water prior to sample collection.

2.2 Baseline Characterization Findings

The baseline characterization better defined the subsurface geology, the nature and extent of contamination in the subsurface. The following discussion provides the findings of this activity.

2.2.1 Subsurface Geology

The subsurface geology underlying FAA-B consists primarily of clayey silt and silty clay overlying weathered shale and limestone bedrock. Laterally discontinuous sand and gravel bodies, ranging in thickness from less than 1-foot to approximately 6-feet, were observed within 10-feet of the ground surface. The depth to bedrock ranges from 20 to 36 ft bgs. These findings are consistent with data collected during previous investigations.

Figure 2-1 shows the locations of the cross sections A-A' and B-B'. Figures 2-2 presents cross section A-A' and Figure 2-3 show cross-section B-B'. The cross sections were developed from the baseline characterization boring logs. As shown on Figure 2-3, SB-16 has a significantly different lithology than MW-9. This is attributed to area disturbance required for the construction of the gun range. It is likely that SB15, MW-09, and SB17 are at the edge of the undisturbed area.

Figure 2-4 presents an isopach (thickness) map of the most prevalent, water-bearing sand/gravel body in the vicinity of FAA-B. As shown on the figure, the sand layer is the thickest in the vicinity of MW-7, thinning to the north and the south. The sand extends to the west, possibly terminating at the side slope of the gun range. Figure 2-4 indicates that the sand stringers are primarily two feet or less in thickness, providing narrow routes for migration. The sand stringers also tend to be discontinuous.

2.2.2 Potentiometric Surface

Groundwater level measurements were collected from individual monitoring points prior to each sampling event. However, because of the time required for sampling, available data were not from a single day. Therefore, a groundwater level measurements were taken on March 31, 2000 from monitoring wells MW-1 through MW-09 and injection wells IN-01, IN-02, IN-03, IN-04, and IN-06 to provide data for interpretation of groundwater flow in FAA-B. The data were plotted on the base map and the lines of equal potential were constructed based on these data. This interpretation is shown on Figure 2-5. As shown on Figure 2-5, the water level data from the injection wells were not incorporated into this interpretation. These data were approximately

0.5 feet lower than the nearby monitoring wells. This may be due to several factors, including not being screened across the full water bearing zones.

The data show the general groundwater flow direction in FAA-B to be towards the southwest. This is influenced by the shallow bedrock to the north and the east of FAA-B and the compacted earthen berm area of the gun range to the west, causing a funnel-like effect to the southwest. The hydraulic gradient in the general area of FAA-B is flat, allowing for varying flow direction components within the area. Overlaying Figure 2-4, water bearing sand isopach, onto 2-5, shows the sand being limited in areal extent. Changes in water pressure may result in preferential pathways to the west prior to pressure equilibrium to the localized prevailing flow direction.

2.2.3 Soil Analyses

Volatile organic contamination of the soil was detected in soil samples collected from 11 of the 26 drilling locations. Table 2-2 provides the results of the soil analyses, detects only; all other parameters analyzed by Method 8260 were below the analytical detection limit. Total VOC concentrations range (in samples with detections) from 69,600 µg/kg in SB08 (4 to 8 ft bgs) to 65 µg/kg in IN08 (10 to 12 ft bgs). Figures 2-6 and 2-7 show the distribution of VOCs and specific parameters detected. As shown on the figures all of the soil detections except SB13 are within 20 ft of MW03 or MW07. Specific compounds detected included TCE and its degradation products, cis-dichlorethylene (cis-DCE) and trans-dichloroethylene (trans-DCE).

Ethylbenzene and xylene were detected in four soil samples collected from the upper 6 inches of soil. Because the concentrations are low in relation to risk-based criteria and present only in the surface soil, these results are not considered further.

The highest concentrations of chlorinated VOCs detected in soil were present in samples (SB08, SB10, and MW07) collected closest to the concrete pad in the drum storage area. The concentrations of VOCs found in the soil decrease with distance west from the pad. One sample (SB11) collected from beneath the pad (east of SB08) had VOCs concentrations just above the detection limit. The soil analyses of SB26 showed the presence of cis-1,2-dichloroethylene (77.8

µg/kg), and trichloroethylene (5.6 µg/kg), both well below the concentrations observed in soil collected during installation of MW-7 (trans-1,2-dichloroethylene 300 µg/kg, cis-1,2-dichloroethylene 2,900 µg/kg, and trichloroethylene 8,400 µg/kg at 12 feet bgs). SB26 was collected at the soil bedrock interface in the vicinity of MW07 showing that minimal vertical migration has occurred. These results indicate that the extent of soil contamination is limited to an area less than 3,000 square feet and the contamination is primarily in the upper portion of the soil column. The location of the soil contamination, and the presence of degradation by-products of TCE, indicates a surface release of TCE occurred near the pad.

2.2.4 Groundwater Analyses

Groundwater sample analyses show a wider distribution of VOC contamination than the soil data. The groundwater samples also show the presence of vinyl chloride, the final degradation product of TCE. Table 2-3 provides the results of the groundwater analyses. Only the parameters detected are listed on the table. All other parameters analyzed by Method 8260 were below the analytical detection limit. A complete list of parameters analyzed by Method 8260 is provided in Appendix C.

Total VOC concentrations in groundwater, in are to be treated ranged from 664 µg/L in a sample collected from SB10, to 8.2 µg/L detected in SB11. Figures 2-8 and 2-9 show the distribution of VOCs and specific parameters detected. In general, the highest concentrations of contamination detected in groundwater correspond to the highest concentrations detected in the vadose zone soil. The data do indicate two areas near the operational area of Facility 92 where total VOC concentration is greater than 100 µg/L in groundwater.

Figures 2-10, 2-11, and 2-12 show the distribution of vinyl chloride, TCE and DCE, respectively, at FAA-B. These show that the highest concentrations of vinyl chloride are found in the vicinity of MW-3. TCE is present in two areas, with the highest concentrations detected in groundwater collected from SB-14 and SB18, which are approximately 90 feet north of MW-3. DCE appears to be the most widely distributed contaminant. The highest concentrations are in the vicinity of MW-7. Analytical data from groundwater samples collected from SB-16 indicate much higher concentrations of VOCs in SB-16 than in adjacent monitoring points (MW-9, SB15, and SB17). Review of field records does not indicate anything unique about in samples collected from SB-16 (i.e., turbidity, and conductivity) as compared to adjacent samples. These data are considered anomalies and are not used for preparing the contours.

These data indicate the groundwater contamination may be the result of a TCE release in the vicinity of the drum storage area. The primary distribution of contaminants extends across the road and towards the gun range, in the direction of the localized groundwater flow direction. As stated in Section 2.2.2, the general groundwater gradient through the area is to the southwest; however the gradient is shallow and actual flow within the sand lens will be influenced more by the shape of the sand than the overall gradient. For example, application of pressure to the northeast portion of the sand will tend to cause groundwater to flow to the east, through the sand, until pressure has equilibrated throughout the area. The source area of this plume appears to be in the vicinity of MW07, SB08, and SB10. Further migration to the west will be restricted due to the gun range.

A second release area is to the north of MW07 is defined by samples collected from SB14 and SB18. It is characterized by the presence of PCE, which was present only in samples from SB14 and SB18.

3.0 Fenton's Chemistry Treatability Tests

Three treatability tests were conducted in FAA-B. Two of the tests were to determine the efficacy of using in-situ chemical oxidation for the destruction of chlorinated hydrocarbons present at the site and the third was to determine the kinetics of anaerobic degradation of vinyl chloride, using hydrogen as the primary electron donor. The procedures for conducting the Fenton's Chemistry Treatability tests and their associated results are presented below.

3.1 Fenton's Chemistry Reaction Mechanisms

A method for the treatment of organic compounds by chemical oxidation is application of Fenton's Chemistry. This reaction, introduced in the 1890's by H. J. H. Fenton, has been widely studied and is utilized by the wastewater industry. The basic reaction for the destruction of a halogenated compound is as follows:

Hydrogen Peroxide + Organo Halide → Carbon dioxide + Water + Chloride

or $H_2O_2 + R\text{-}X \rightarrow CO_2 + H_2O + Cl^-$

The actual oxidation of the organic compound is driven by the hydroxyl free radical formed during the Fenton's reaction. The preferred Fenton's reaction is as follows:

$$H_2O_2 + Fe^{+2} \rightarrow OH^{\cdot} + OH^- + Fe^{+3}$$

Application of this process to in-situ groundwater remediation is accomplished by injection of hydrogen peroxide and a catalyst (ferrous iron) into the saturated zone. Successful application of this technology is dependent upon physical and chemical conditions in the subsurface zone to be treated. Experience by GeoCleanse® shows that a pH of less than 8.0 and a hardness of less than 400 mg/L are required for successful operation. As stated in the Work Plan, the pH is typically near neutral (7.0) and the hardness is approximately 190 mg/L. Through the test, field measurements (IT Corporation and GeoCleanse) of pH ranged between 6.0 and 8.0. In addition, alkalinity measurements, expressed as $CaCO_3$, ranged between 226 mg/L and 457 mg/L, indicating hardness near or below 400 mg/L.

In most cases, the amount of reagents injected depends on sufficient delivery of the reagents to a volume of the saturated zone rather than the stoichiometric requirements. Following injection, no material is recovered; hydrogen peroxide disassociates to water and oxygen, iron is precipitated out of the water as ferric iron, and chlorinated organic compounds disassociate to carbon dioxide, water and chloride.

Fenton's chemistry relies on the formation of the powerful, but unstable and ephemeral, hydroxyl free radical in the vicinity of the organic compound to be destroyed. Thus, the goals of in-situ application of Fenton's chemistry are to:

1) Create the free radical in the formation in contact with the contaminant
2) Establish an effective radius of influence from each injector
3) Deliver the reagents to the subsurface in a quick, safe, and economical manner.

During the reaction sequence, the organic compounds are successively converted to shorter chain mono- and di-carboxylic fatty acids. These compounds are naturally occurring substances that are further converted to carbon dioxide and water by subsequent reactions.

3.2 Application Method

Geo-Cleanse® International provided equipment, labor and material to inject Fenton's Reagent into the subsurface. The Geo-Cleanse® process is a proprietary technology to inject hydrogen peroxide and trace quantities of metallic salts into the subsurface via a patented methodology and equipment (US Patents 5,525,008 and 5,611,642). This in-situ oxidation system is capable of complete, non-selective oxidation of organic compounds in soil and groundwater.

The patented Geo-Cleanse® injection methodology contains a mixing head that promotes mixing of reagents and stimulates circulation of groundwater. This promotes rapid reagent diffusion and dispersion through the impacted zone. The mixing heads are equipped with check valves and a constant pressure delivery system that ensures that catalyst and peroxide do not mix together in the sealed injector system until they reach the screened interval of the injector which is at the zone of contamination/treatment. This eliminates the chances of reaction within the injector system and maximizes the chances of dispersion and diffusion into the subsurface. The injectors are also specially designed to withstand the high temperatures and pressures resulting from the Fenton's reaction.

3.3 Injection Well Installation

Following completion of the baseline characterization, eight injection wells were installed for the Fenton's Chemistry treatability test. The locations and screened intervals of the injection wells were based on the findings of the baseline characterization, targeting the upper water-bearing zone, where the highest concentrations of VOCs in groundwater were detected. The target stratum is between 12 to 16 ft bgs.

The injection well locations are shown on Figure 2-1. As shown on Figure 2-1 several of the injection well locations (IN01, IN02, IN04, IN07) correspond to soil boring locations. These were direct overdrill of the soil boring locations (SB10, SB08, SB01, and SB02), done to minimize the potential short circuiting of treatment chemicals to the surface. Injection wells were installed using 4-1/4-in.-I.D. HSA techniques. Well construction specifications included the following:

- 1-1/4-in.-diameter by 4- to 6-ft long, stainless steel drive points
- 60 gauge (010-slot) screen (typically Simmons brand well points)
- 1-1/4-in. couplings, Schedule 80 black iron
- 1-1/4-in. riser pipe, Schedule 80 black iron

- 1-1/4-in. threaded caps, Schedule 80 black iron
- 1 ft of standard drilling bentonite per injector

Specialized grout ratio (94 lbs. Type 1 Portland Cement: 5 lbs. bentonite gel: 7 gal water).

3.4 Vent Wells

Four vent wells were installed on the periphery of the injection zone as pressure relief points, thereby minimizing the chance of oxidant surfacing near drums stored at Facility 92. Three of the vent wells (VW1, VW2, and VW3) were overdrills of soil borings (SB07, SB03, and SB04) completed as part of the Baseline Characterization. The fourth vent well (VW4) was installed through the Facility 92 concrete pad, approximately 16 feet east of IW02. The vent wells were completed between 8 and 18 feet below ground surface, with a 10 foot section of 2" diameter schedule 40, 10 slot well screen. The sand pack was a #5 sand, placed to one foot above the top of the screen. The sand was followed by one foot of bentonite pellets, and the balance filled with a bentonite/grout mix. Each of the vent wells had a two-foot surface riser.

3.5 Injection Activities

This treatability test commenced on 26 October 1999 and proceeded through 29 October 1999. A detailed report of the Fenton's Chemistry Treatability injection activity was prepared by Geo-Cleanse® and is included in Appendix D. The Geo-Cleanse® report provides the results of process monitoring (CO_2, O_2, pH, alkalinity, iron, hydrogen peroxide, and chloride) conducted during the injection. This document presents a summary based on the information in the Geo-Cleanse® report and other field data collected during the test.

Fenton's Reagent was in injected into each of the eight injection wells, one vent well (VW4) and two monitoring wells (MW03 and MW07). The decision to inject to the vent well and the monitoring wells was made unilaterally by Geo-Cleanse® based on performance monitoring conducted during the test, these data showed the presence of oxygen in the headspace and hydrogen peroxide in groundwater collected from the monitoring wells as well as the presence of organics. This indicated incomplete treatment in this portion of the treatment zone. Injection to the monitoring wells provided for more complete treatment of the targeted zone. Regarding the vent well, peroxide was not detected. Therefore, reagent was injected to VW4 to ensure this portion of the target zone received treatment. Table 3-1 shows the approximate quantities and concentration of reagents injected into each of the wells. Approximately 1,100 gallons of 25 percent hydrogen peroxide, 1,200 gallons of 50 percent hydrogen peroxide and 4,600 gallons of ferrous sulfate catalyst (approximately 100 ppm $FeSO_4$) were injected to the subsurface of FAA-B over the 4-day period.

The injection to the shallow sand lens proceeded without incident. No pressure build up was observed and there was no surfacing of reagents, indicating that the reagents were being delivered to the aquifer easily. Based on field observation of headspace oxygen levels in monitoring wells, a radius of influence of at least 15 ft was achieved. Figure 3-1 shows the approximate area treated by Fenton's Reagent.

3.6 Performance Monitoring Results

Groundwater samples were collected from MW03, MW07, IN01, and IN07 during injection activity (27-Oct-99, 28-Oct-99, and 29-Oct-99), and following completion of injection (01-Nov-99, 15-Nov-99, and 15-Dec-99). These samples were collected to measure the effectiveness of the Fenton's Reagent in reducing VOC concentration in groundwater. Collection of a number of samples over time allows measurement of both the short- and long-term effectiveness of the treatment method. The on-site mobile laboratory analyzed samples collected during injection activity. All samples collected after 29-Oct-99 were analyzed at an off-site contract laboratory.

All of the wells sampled for performance monitoring were used as injection points for the Fenton's Reagent. The injection of material into a well will displace the groundwater in the immediate vicinity of the well and dilute groundwater further from the well. In addition, free radical generation would be expected to be at it's maximum in close vicinity to the wells, before any resulting dilution of the iron concentration in groundwater. Any of these factors could bias the data. However, over time the water bearing zone is expected to equilibrate, providing a better picture of the actual conditions.

All samples were collected following FP 6-5. A slight variance was used during these sampling events. Initial purge water was checked for the presence of hydrogen peroxide using Merckoquant test strips (0-100 mg/L), prior to using the Horiba water quality meter (used for pH, conductivity, turbidity, and temperature). If hydrogen peroxide was found to be present, the water meter was not used as the peroxide would damage the membrane on the probe. Hydrogen peroxide was present in groundwater during the 1-Nov-99 sampling event, therefore no field parameters were measured. Hydrogen peroxide was not present in the subsequent sampling events, indicating full breakdown of the hydrogen peroxide and equilibration of the water bearing zone.

Analytical results are summarized on Table 3-2, showing both the pre and post injection sample analyses. Figures 3-2, 3-3 and 3-4 provide a spatial distribution of the VC, TCE, and DCE, including estimated isopleths for each of the contaminants in the areas treated with oxidants. Figures 3-5 to 3-10 show temporal distribution of the individual contaminants for MW-3 and MW-7. Comparing Figures 3-2, 3-3, and 3-4 with Figures 2-10, 2-11, and 2-12, and assessing the data in Table 3-2 and Figures 3-5 to 3-10 results in the following conclusions.

- Within the area treated by Fenton's Reagent, the areal extent of VC contamination in excess of 50 ppb, has been reduced by more than 50%.

- Following treatment with Fenton's Reagent, VC in excess of 100 ppb was not detected in samples collected within the treatment zone (MW-3, MW-7, IN01, IN07). The maximum detection as 72 ppb (IN07). Two samples collected during the baseline investigation (IN05 and IN08) had VC concentrations in excess of 100 ppb, with a maximum detection of 300 ppb.

- Within the area treated by Fenton's Reagent, the areal extent of TCE contamination in excess of 10 ppb, has been reduced by more than 50%.

- Within the area treated by Fenton's Reagent, the areal extent of DCE contamination in excess of 10 ppb, has increased by more than 50%.

- The decrease in TCE and the increase in DCE concentration in the treatment zone may indicate the breakdown of TCE and subsequent formation of DCE. However, it may also indicate a redistribution of contaminants due to the injected fluids.

- A shown in Table 3-2, sampling results indicate vinyl chloride, TCE, and DCE present in groundwater were significantly reduced due to the oxidant addition. Samples collected during and immediately following the conclusion of the Fenton's Reagent test showed vinyl chloride concentrations reduced to below detection, and TCE and DCE concentrations reduced by an order of magnitude.

- Samples collected 2 weeks (15-Nov-99) and 6 weeks (15-Dec-99) after conclusion of the test indicated a rebound of TCE, DCE, and vinyl chloride. There are two possible scenarios for the rebound to occur. The first, and most likely scenario, is leaching of contaminants from the vadose zone soils above the treatment zone. During injection, the pressure used to deliver the reagent caused groundwater to mound into the vadose zone an estimated 2 ft. Fenton's Reagent contact with the vadose zone is expected to have resulted in the destruction of the residual organics in the vadose zone. However, the natural organic material present in the vadose zone would be expected to consume Fenton's Reagent, inhibiting treatment efficiency. Consumption of natural organics was also occurring in the water-bearing zone, but at a lower rate due to the lower amount of natural organic material in the water bearing zone. Once injection activity was completed, the water table returned to pre-test levels. Water draining from the vadose zone back to the water-bearing strata would carry organics to the water-bearing zone, resulting in the detection of TCE and DCE in the post injection samples. Monitoring data show that prior to injection DCE and VC are the dominant contaminants present in the groundwater. Immediately following injection TCE and DCE concentrations are similar percentages of the total VOCs then trend towards a greater imbalance (greater DCE and VC) over time. A second explanation for the rebound of the TCE, DCE, and vinyl chloride may be due to incomplete treatment in the water-bearing zone, in particular in clay present in the water-bearing strata. The results also may be related to dilution of the water bearing zone by the injected reagents. However, based on the information above, we believe this is unlikely.

3.7 By-Product Formation

Several suspected reaction byproducts, Acetone and methyl ethyl ketone (MEK), were detected in samples collected within the treatment zone. Acetone and MEK appear to be byproducts of the oxidation of natural organic material under acidic conditions such as is present for the Fenton's Reaction.

Initial detections were observed in samples collected near the conclusion of the injection period. Subsequent detections were observed in performance monitoring samples collected after the completion of the injection period. Acetone was detected in all but one of the samples (IN01 on 15-Dec-99) collected following the completion of the injection. MEK was detected in all but one (MW-3) collected on 15-Nov-99, but was below the detection limit (12.5 ppb) in all of the samples collected on 15-Dec-99. Acetone data for MW-3 and MW-7 are displayed on figures 3-11 and 3-12. MEK detections were insufficient for meaningful graphical display. As shown in the graphs, the concentration of acetone in groundwater decreased rapidly from 1-Nov-99 to 15-Nov-99 and was subsequently detected in only one of the samples (IN07) collected on 15-Dec-99. The decrease of the Acetone and the MEK is likely due to biodegradation in the highly oxygenated conditions resulting from the peroxide addition.

Groundwater samples collected on 16-Feb-00 were also analyzed for the presence of acetone and MEK. These samples were collected to evaluate the effectiveness of potassium permanganate for oxidation of chlorinated hydrocarbons present in the subsurface. All results (Table 4-5) were below the analytical detection level.

4.0 Potassium Permanganate Treatability Tests

An in-situ chemical oxidation treatability test using potassium permanganate was also conducted to determine the efficacy of for the destruction of chlorinated hydrocarbons at FAA-B. The procedures for conducting this test and the associated results are presented below.

4.1 Permanganate Reaction Mechanisms

Potassium permanganate ($KMnO_4$) is widely used in the water treatment industry to oxidize and precipitate dissolved metals and in the sewage treatment industry to treat sulfide odors. $KMnO_4$ will react with and oxidize a wide range of common organic contaminants, relatively quickly and completely. In particular, $KMnO_4$ reacts rapidly with the non-conjugated (i.e., non-aromatic) double bonds in chlorinated ethenes such as TCE, PCE, DCE isomers, and vinyl chloride. Permanganate is also effective with BTEX and simple PAHs. The redox potential is a function of oxidant concentration and solution pH. As a general rule, $KMnO_4$ will oxidize anions more readily than neutral molecules that are, in turn, more readily oxidized than cations.

The basic reaction for the destruction of organo-halides is as follows:

Potassium Permanganate + Organo Halide → Manganese Oxide + Carbon dioxide + Water + Chloride + Potassium

or $KMnO_4 + R\text{-}X \rightarrow MnO_2 + CO_2 + H_2O + Cl^- + K^+$

The balanced chemical equations for permanganate oxidation of selected chlorinated ethenes are as follow:

PCE: $4KMnO_4 + 3C_2Cl_4 + 4H_2O \rightarrow 6CO_2 + 4MnO_2 + 4K^+ + 12Cl^- + 8H^+$

TCE: $2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$

DCE: $8KMnO_4 + 3C_2H_2Cl_2 \rightarrow 6CO_2 + 8MnO_2 + 8K^+ + 6Cl^- + 2OH^- + 2H_2O$

VC: $10KMnO_4 + 3C_2H_3Cl \rightarrow 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$

Several observations can be made from these equations. The lower the degree of chlorination, the more alkaline the reaction becomes (the oxidation of PCE and TCE produces acid, whereas the oxidation of DCE and vinyl chloride consumes acid). Also, the lower the degree of chlorination, the more permanganate is required to oxidize the chlorinated ethene.

Disassociation of the potassium permanganate provides the electrons required for the oxidation of the hydrocarbons. Application of this to in-situ groundwater remediation is accomplished by injection of dissolved potassium permanganate into the saturated zone. Potassium permanganate is fairly soluble at 20^0C (64 g/L) and can easily be made up to >3 percent solutions. Higher concentrations are possible with hot water (solubility is 250 g/L or 25 percent at 65^0 C). The standard application level is between 1 to 6 percent, injected at ambient temperature. Because of the high strength and reactivity, permanganate can be used to treat a wide range of contaminant levels detected in groundwater and soil, including DNAPLs. These high strength solutions are relatively stable and generally spent only through reaction with the contaminant or other reduced species (iron, natural organics). The permanganate ion, MnO_4^-, is not thermodynamically stable in water and tends to (very slowly) oxidize water with the evolution of oxygen:

$$4MnO_4 + 4H^+ \rightarrow 4MnO_2 + 2H_2O + 3O_2$$

This reaction is so slow as to not be a significant concern for in-situ chemical oxidation and residual permanganate in aquifers has been observed for several months after injection.

The effectiveness of treatment is a function of three factors: the kinetics of the reaction between the permanganate and the contaminant, the contact between the oxidant and the contaminant(s), and competitive reactions of permanganate with other reduced/oxidizable species. If the contaminant is reactive (e.g., chlorinated ethenes), and sufficient oxidant has been added to overcome the demand from other reduced species, the limiting factor to the successful application of in-situ oxidation is the transport of the oxidant to the areas of contamination. The oxidation of TCE and DCE by permanganate is, compared to the time to transport the permanganate to the treatment zone, an essentially instantaneous reaction. By contrast, travel times for the permanganate to migrate away from the injection point may be on the order of a day to weeks, depending on the spacing of the injection points, the injection pressure, and the rate of groundwater flow. Low permeability soils and highly heterogeneous soils, therefore, require more sophistication in application approach than high permeability, homogeneous soils.

4.2 Bench-Scale Studies

Bench-scale treatability tests were performed to determine the effect of oxidizable compounds in the soil and groundwater on the ability of potassium permanganate to oxidize vinyl chloride and TCE in the groundwater. Potassium permanganate is not a selective oxidizing compound. Thus, natural organics and other oxidizable compounds present in the site soil and groundwater will compete with the targeted chlorinated ethenes for the permanganate. Soil and groundwater slurries were used in these batch experiments to:

1) Evaluate the consumption of oxidants by natural organic material present in the upper water bearing sand (both soil and groundwater),

2) Estimate the reaction rate of the oxidant on TCE and vinyl chloride when present in the same soil/groundwater matrix as the subsurface.

The bench-scale tests were conducted at the U.S. EPA Test and Evaluation (T&E) Facility in Cincinnati, Ohio. Two different phases of the tests were completed concurrently. The first phase investigated the soil oxidant demand, and the second phase investigated the reagent dosage and rates of vinyl chloride and TCE reaction. Samples collected for the bench scale tests were collected from the upper water bearing zone (12-14' bgs). Soil samples were collected in a 1-gallon, sealable, plastic bag. The sample was chilled to 4 ºF with ice and stored in a refrigerator at 4 ºF, until used for the test. The water was collected in 1-liter amber jars and chilled to 4 ºF prior to use in the bench scale tests. As a follow-up to the soil oxidant demand, samples of contaminated soil were also sent to an offsite laboratory and analyzed for chemical oxygen demand (COD). The anticipated volume of potassium permanganate required for the treatability tests was then calculated from these tests.

4.2.1 Soil Oxidant Test

The first bench test measured the gross oxidant demand of the soil to estimate the expected permanganate uptake from oxidizing native organic material as well as the chlorinated ethenes. The soil gross oxidant demand was determined by titrating a 20-percent soil slurry against a 5-percent potassium permanganate solution. The oxidation-reduction potential (ORP) was used as the indicator for this titration. The ORP is a measure of the state of oxidation of the system with a high ORP corresponding to a high oxidant concentration. The 5 percent potassium permanganate solution had an ORP of approximately 605 mV whereas the initial soil slurry had an ORP of approximately 270 mV. As permanganate is added to the slurry, the ORP is expected to initially increase, and, then, as this permanganate is consumed by organics in the soil, the ORP is expected to decrease. The ORP is measured several times during the course of the tests and is plotted against time. The titration is considered to have reached the end-point when the ORP does not decrease even several hours after the last aliquot of permanganate has been added.

The soil slurry was composed of 40 grams wet soil from MW07 and 160 grams deionized water. The potassium permanganate solution was produced by adding 5 grams potassium permanganate powder to 100 mL of deionized water. A 20-percent soil slurry was chosen to allow sufficient fluidity of the mixture to provide intimate contact between the permanganate and organics in the soil.

A 250-mL amber glass jar containing the slurry was placed on a magnetic stir plate. A Teflon®-coated magnetic stirrer provided mixing for the slurry and potassium permanganate during the titration. A burette was used to add 4-, 5-, 6-, and 7-mL aliquots of potassium permanganate solution, respectively, to the slurry in each of four continuously-mixed jars. Caps were placed on the jars to prevent splashing and evaporation, and the slurries were allowed to mix for approximately 48 hours. The ORP measurement after this time interval indicated that the permanganate added to each of the jars had been consumed, i.e., the titration had not reached it's end point. An additional 3-mL aliquot of potassium permanganate solution was thus added to each jar and the slurries were allowed to mix for an additional 10 hours. ORP measurements indicated that the second addition of potassium permanganate solution appeared to have oxidized the remaining organic compounds.

Figure 4-1 shows a plot of the ORP of the slurry and the volume of potassium permanganate solution that was added to the slurry. The point of inflection (approximately 9 mL potassium permanganate solution) is the quantity of 5-percent potassium permanganate solution required to oxidize 40 grams of soil. This volume estimate was extrapolated to calculate the volume of 2 percent potassium permanganate solution required to treat the soil in the treatability tests using the following assumptions:

- Treatment radius = 15 ft
- Treatment depth = 5 ft
- Treatment volume = 3,500 cubic feet of soil.

The calculations showed that 22,000 gallons of 2 percent potassium permanganate solution would be required to treat the soil at each injection point.

After measuring the ORP, the slurry from each jar was centrifuged at 3000 rpm for 30 minutes to separate the soil and water fractions. The water fraction had a purple color characteristic of residual potassium permanganate. The water and soil fractions of the slurry were then analyzed for VOCs by U.S. EPA Method 8260. The analytical results are shown in Table 4-1. At the end-point of titration for this test, contaminant concentrations in both, the soil and groundwater, were found to be non-detect. Acetone was detected (70, 52, and 71 ug/L) in the intermediate water samples (elutriate from centrifuge) analyzed.

4.2.2 Slurry Permanganate Test

The slurry permanganate test was used to determine the reaction rate of permanganate on vinyl chloride and TCE. A 50 percent soil and groundwater slurry was reacted at three different permanganate doses. Five- percent potassium permanganate solution was dosed to each slurry at 3, 7, and 15 times the stoichiometric requirement for destruction of the VOCs present in the slurry. The slurries were allowed to react and were subsequently sampled three times over a 24-hour period.

The following balanced chemical equations between potassium permanganate and selected chlorinated ethenes (perchloroethylene [PCE], TCE, dichloroethylene [DCE], vinyl chloride [VC]) were used to determine the quantity of potassium permanganate required for each slurry:

PCE: $4KMnO_4 + 3C_2Cl_4 + 4H_2O \rightarrow 6CO_2 + 4MnO_2 + 4K^+ + 12Cl^- + 8H^+$
TCE: $2KMnO_4 + C_2HCl_3 \rightarrow 2CO_2 + 2MnO_2 + 2K^+ + 3Cl^- + H^+$
DCE: $8KMnO_4 + 3C_2H_2Cl_2 \rightarrow 6CO_2 + 8MnO_2 + 8K^+ + 6Cl^- + 2OH^- + 2H_2O$
VC: $10KMnO_4 + 3C_2H_3Cl \rightarrow 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$

The slurry was composed of 120 grams wet soil from MW07 and 120 grams groundwater from MW03. Table 4-2 shows the initial contaminant concentrations in the soil and groundwater that was used to calculate the potassium permanganate additions. The potassium permanganate solution was prepared in the manner described in Section 4.2.1.

Twelve 250-mL centrifuge bottles were filled with slurry, capped, and placed onto a shaker table to provide mixing. These bottles represented the following test conditions:

No. of Bottles	Volume of Permanganate Added	Test Condition
3 bottles	0 mL	Control
3 bottles	0.25 mL	3X Stoichiometric requirement
3 bottles	0.58 mL	7X Stoichiometric requirement
3 bottles	1.25 mL	15X Stoichiometric requirement

A syringe was used to add the potassium permanganate solution to the centrifuge bottles.

One sample of each dose, except the control samples, was sacrificially sampled after 4 hours, 8 hours, and 24 hours reaction time. When a dose was sampled, the ORP was measured, and 1 gram ferrous sulfate was added to the sample to stop the reaction. Control samples were handled differently. One control sample was quenched and analyzed at time zero. The other two controls were sampled and analyzed after 24 hours, one was quenched with ferrous sulfate and the other was not. This allowed a comparison to see if the ferrous sulfate affected the analytical results. The data show no affect from the ferrous sulfate addition. Following addition of the ferrous sulfate, each of the samples was then centrifuged and the water and soil fractions were analyzed for VOCs by U.S. EPA Method 8260.

Table 4-3 summarizes the results of the slurry test. Based on the decreasing ORP values, the permanganate oxidation requires over 24 hours to run to completion. Based on the contaminant concentrations, more than 15 times the stoichiometric ratio of potassium permanganate is required to oxidize all of the organic contaminants. This volume of permaganate is consistent with that found to be consumed by the oxidant demand test.

To provide an independent corroboration of the oxidant demand by the soil, a soil sample was analyzed for COD (by U.S. EPA Method 410.0) by an external laboratory. The COD of the soil was found to be between 0.73% and 1.06%. By comparison, the calculated COD based on permangante consumption in this bench-scale test is 0.17%. This difference in COD measurements may be attributed to the different oxidants and temperatures used in the two methods and simply confirms the presence of a high level of organic material in the soil.

4.3 Injection Activity

The hydrogeology of the target treatment zone is the primary factor in the selection of the method(s) for the delivery of permanganate into aquifers. The subsurface at FAA-B is a silty-clay interspersed with sand stringers. This subsurface exhibits a wide variability in permeability between the clay and the sand and there is the need to treat the groundwater in multiple layers. Thus, the method for delivery of the permanganate needs to accommodate differences in permeability and multiple treatment levels. For this type of subsurface, a direct-push technique has been successfully used to deliver the oxidant.

Delivery of the potassium permanganate to the subsurface involved hydraulically pushing a pipe/probe, fitted with a screen (GeoProbe® screen Point 15), into target treatment depth. The probe tool was then drawn back to expose the screen to the formation. Potassium permanganate solution (2 percent $KMnO_4$) was then pumped through the pipe string and through the screen to the formation, using a GeoProbe® GS1000 Grout Machine. Permanganate injection activities took place from 2-Nov-99 through 11-Nov-99. Injection was completed by IT personnel with the assistance of AST Environmental.

4.3.1 Injection Locations

Permanganate injection locations were determined based on the results of the baseline investigation and the Fenton's Chemistry treatability study. Locations were selected based on the highest concentrations of VOCs observed during the baselines study that were outside of the apparent influence of the Fenton's Reagent injection. Injection points were spaced 20 ft apart, providing for a 10-ft radius of influence. Unlike Fenton's Reagent, potassium permanganate remains stable in water provided it is not consumed by reaction with organics. Therefore the injection volume and pressure does not need to be such that a certain soil volume must be fully treated by permanganate. The permanganate is introduced to the formation, then transported by diffusion and natural groundwater flow. Oxidation of organics then continues as long as permanganate is available. Considering the 2-foot screened interval of the injection screen and injection of 80 gallons of permanganate solution, the initial estimated radius of influence is 2.5 feet. Diffusion and groundwater flow was expected to treat the balance of the distance (5 feet) between injection points.

Injection intervals were based on baseline characterization data. Figure 4-2 shows the permanganate injection intervals. Prior to injection at each location, boring logs and analytical data collected during the baseline investigation were reviewed to determine injection intervals. Zones of contamination were targeted, injecting 80 gallons of 2 percent solution into each injection interval. Figure 4-3 shows the injection locations. Table 4-4 provides a list of injection points, injection intervals, and volume of permanganate injected.

4.3.2 Performance Monitoring Results

Performance monitoring for measuring the effectiveness of the potassium permanganate injection included exploratory probes in the vicinity of injection points, collection of groundwater samples MW08, and MW09 and from Geoprobe borings, and collection of a soil sample in the vicinity of an injection point. The varied sampling approach was taken to measure the migration of the permanganate, measure any change in groundwater concentration of VOCs, and to measure and change in soil concentration of VOCs. All samples collected after injection activities were submitted to a off-site contract laboratory for analysis.

Exploratory probes were completed in the vicinity of MW09, 2 weeks after the initial injection. Five exploratory probes were completed between permanganate injection point 05 and MW09. Total distance between the two points is 13 feet, therefore the exploratory probes were completed approximately two feet apart at a depth of 12-16 feet bgs, which is consistent with the interval treated with permanganate and the completed interval of MW09. This effort showed that the permanganate solution had not migrated more than 5 ft from the injection point. Water samples were collected from all 5 exploratory probes, permanganate injection points 4 and 5 and MW09.

It was also observed that in one of the injection points that the permanganate had been consumed (colorless sample), apparently by the natural organic material. Groundwater samples collected from these locations were examined for residual potassium permanganate by using a spectrophotometer. This analysis showed permanganate to be present only in the vicinity of injection point 5 (approximately 50 ppm). Two feet from injection point 5 the permanganate concentration was estimated to be greater than 50 mg/L and four feet from injection point 5 the permanganate concentration was estimated to be approximately 35 mg/L. The results of the spectrophotometer analyses are presented in Appendix E. The remaining injection points that could be sampled and MW09 did not have any residual permanganate.

Groundwater samples were collected from MW08 and MW09 on 15-Nov-99 and 15-Dec-99 to measure post treatment concentrations of VOC in groundwater. MW08 and MW09 were not affected by the Fenton's Chemistry injection and were specifically targeted during the permanganate injection activity. Samples were collected in accordance with FP 5-6 (purging) and FP 6-5 (sampling). Analysis of samples collected on 15-Nov-99 show no apparent change in VOC concentration in MW09 but do show a decrease in MW08 from 76 µg/L to below detection (Table 4-5). This may indicate the effectiveness of the permanganate due to the close proximity of an injection point (approximately 5 ft) from MW08. Analysis of samples collected on 15-Dec-99 indicates a rebound of VOC levels in MW08 and possible decrease in MW09.

On 16-Feb-00 groundwater samples were collected at five locations using a GeoProbe. These locations (SB20, SB21, SB22, SB23, and SB25; see Figure 4-3) were selected based on the close proximity to samples collected during the baseline characterization and permanganate injection points. These samples were collected at predetermined intervals that were selected based on injection depths. The borings were not logged because of the close proximity to borings logged during the baseline investigation, and to speed the collection of the samples. The samples were collected in accordance with the method outlined in Section 2.1.2 of this report. Analytical results (Table 4-5) indicate a decrease in VOC concentration in four of the five samples collected. The fifth sample showed an increase in groundwater VOC concentration. Samples indicating a decrease were SB20, SB21, SB22, and SB23. These locations were in the vicinity of SB18, SB07, SB07, and SB13, respectively.

One soil sample (SB25) was collected in the vicinity of SB13. SB13 was selected based on VOC levels observed in the soil during the baseline characterization and the soil at 10 to 22 ft bgs was specifically targeted during the permanganate injection. Analytical results indicate a six-fold decrease in VOC in soil. Given the normal variability in soil results, some caution is advised in interpreting these data; however, the results are encouraging.

5.0 Hydrogen Injection Test

5.1 Test Procedure and Activities

The hydrogen injection treatability test was conducted by application of a "push-pull" test methodology. Push-Pull tests, as described by Istok, et. al. (1997), consist of pulse type injection (push) of a test solution into the saturated zone followed by extraction (pull) of the test solution/groundwater mixture from the same well. The test solution contains a tracer and reactive solutes selected to investigate microbial activity. For FAA-B the reactive solute is hydrogen, provided as an electron donor for anaerobic degradation of vinyl chloride and the tracer used was sulfur hexafluoride.

The method essentially consisted of the following steps:

1. Extraction of a known quantity (42 gallons) of groundwater from the test area.
2. Addition of hydrogen and of tracer (sulfur hexafluoride) to the extracted groundwater and through mixing to create a homogeneous test solution. The initial concentration of hydrogen was 0.23 mg/L and the sulfur hexafluoride was 17 mg/L.
3. Collection of a sample of the water for analysis of the presence of VOCs, hydrogen, and tracer.
4. Contact/reaction time (24 hours) to allow system reaction.
5. Extraction ("pull") of the test solution from the formation. Samples will be collected over time and analyzed for the presence of tracer and hydrogen.
6. Final sampling of the test well and analysis for the presence of hydrogen, tracer, and VOCs.

Prior to conducting the test, a groundwater sample was collected from the test well and analyzed for the VOCs, dissolved oxygen, temperature, pH, and conductivity. Sample collection was conducted as previously described.

The amount of fluid injected was calculated based on the saturated thickness of the water bearing zone, the radial distance from the well for the study treatment zone, and the casing and sand pack volume. The well completion log for SP11-MW03 shows that the well was installed in a 6-inch-diameter borehole using 2-inch-diameter well casing material. The screened interval is 5 ft, corresponding to a water bearing sand lens of approximately the same thickness. Istok, et. al., used a radial distance of 25 cm from the outside edge of the sand pack as the treatment zone. Using the 25 cm radial distance used in the literature, the monitor well construction dimensions, and the thickness of the water bearing sand lens, a total volume of 43 gallons was extracted and reinjected to the formation (see Appendix E for the calculation).

Water was pumped from SP11-MW03 to a clean, 55-gallon drum. Hydrogen and sulfur hexafluoride were added to the water using submerged diffusers. Prior to injection, a sample was collected for analysis of hydrogen and sulfur hexafluoride to establish the initial injection concentrations. The initial concentrations of the hydrogen and sulfur hexafluoride were 0.232 and 17 ppm, respectively.

The test solution was then injected back into the formation at a rate (0.9 L/min) to minimize mounding in the extraction well. Once the full volume was injected into the formation, the system was allowed to rest for approximately 20 hours.

Following the rest period, the test solution was extracted at a rate (0.9 L/min) to maintain the drawdown in the extraction well at less than 20 cm. Once sufficient volume (3 gallons) was removed to purge the well casing and the sand pack, samples were collected for every 5 liters of water extracted for hydrogen and sulfur hexafluoride analysis. Samples for hydrogen analysis were sent off site for analysis. Sulfur hexafluoride samples were analyzed by GC/MS using the mobile laboratory. Field data recorded included elapsed time and cumulative volume extracted for each sample collected. The work plan included collection of a groundwater sample for VOC analysis prior to and after the push-pull test. A sample was collected prior to the test, however the post test sample was not collected due to oversight. Given the short duration of the test these data were not expected to show a significant change in the VOC concentration in groundwater.

5.2 Monitoring Results

Monitoring data (Table 5-1) are presented on Figure 5-1, showing normalized hydrogen and normalized sulfur hexafluoride results (the normalized concentration for each parameter equals the measured concentration divided by the initial concentration). Figure 5-1 shows that the hydrogen recovery was less than the sulfur hexafluoride recovery, indicating loss due to uptake for biodegradation.

Mass recovery of hydrogen and sulfur hexafluoride was calculated by integration of concentration versus volume curve. The differences between the normalized concentrations were analyzed using a one tailed t test. The null hypothesis tested was: is the average difference = 0. The results of the analysis shows that the null hypothesis is rejected ($p=0.005$), indicative of a significant difference between the recoveries of the sulfur hexafluoride and the hydrogen (see Appendix E for the calculation)

The sulfur hexafluoride recovery was much less than expected. It was expected, based on literature reviews, that over 80 percent of the sulfur hexafluoride would be recovered in the extraction portion of this test. However, less than 5 percent of the original sulfur hexafluoride mass was recovered during the test, indicating significant diffusion losses over the 20 hr resting period.

These results can be used to calculate a zero order rate constant for anaerobic degradation of chlorinated hydrocarbons, including vinyl chloride. A zero order rate constant implies that the reaction rate is independent of the concentration of the reacting material. This may be true for this case, as the rate may be dependent upon the population of anaerobic bacteria in the subsurface or some other factor not measured during the test. The degradation rate may be first order (concentration dependent), particularly in the initial stages of the reaction. However, the data collected during this test do not indicate a first order behavior. This may be indicative of when the data were collected. Conducting the extraction phase of the test with a shorter (or no) rest phase may have yielded a first order relationship.

The zero order rate constant is computed by dividing the quantity of reactant consumed by the test solution injection volume and the mean residence time. Consumption of the hydrogen is defined as the difference between the initial mass and the recovered mass minus the loss due to diffusion. Based on the data collected during this injection test, the zero order reaction rate for the chlorinated hydrocarbons present in MW03 is $5x10^{-5}$ mmols/L-hr. Calculations are included in Appendix E.

In addition to these data, oxygen in the headspace was measured in MW03 prior to start up of the Fenton's Chemistry treatability test. Typically, the oxygen level in the headspace is at or near ambient conditions (20.9 percent). As measured on 27-Oct-1999 the oxygen level in the MW03 headspace was 0 percent. This indicates that anaerobic conditions had been achieved and were being sustained in groundwater in the vicinity of MW03.

6.0 Summary and Conclusions

Three treatability studies were completed at FAA-B on the WPAFB to determine the efficacy of each of the techniques for the remediation of VOCs present in the groundwater. The studies included Fenton's Reagent injection, potassium permanganate injection, and hydrogen injection. Fenton's Reagent and potassium permanganate were injected for the chemical oxidation of the contaminants. Hydrogen was injected to the saturated zone to promote anaerobic degradation of the vinyl chloride.

6.1 Summary

Prior to conducting the treatability tests, a baseline characterization was conducted to better define the nature and extent of contamination and to delineate the source area of vinyl chloride contamination in FAA-B. The baseline characterization defined two areas of groundwater contamination and the presence of chlorinated volatile organic compounds other than vinyl chloride. One area, the larger of the two, is defined by the presence of TCE and associated degradation byproducts. The second is defined by the presence of PCE and associated degradation byproducts. One area of soil contamination was defined. Based on these data it appears that the contamination is the result of releases from the drum storage area.

The extent of the upper water bearing sand and the potentiometric surface in the FAA-B indicate that preferential flow paths are present which result in groundwater flow from the suspected release area towards MW09. The extent of the upper water bearing sand and it's relationship to the potentiometric surface in the area was discussed in Section 2.0 of this report and shown on Figures 2.4 and 2.5. The presence of the gun range and the resulting groundwater flow barrier due to the range limits the migration of groundwater contaminants to the west.

Hydrogen injection was the initial test conducted. Hydrogen saturated water was injected to the subsurface, then extracted, to collect data for determination of the reaction rate constant for the anaerobic degradation of the chlorinated hydrocarbons. Hydrogen was added as the primary electron donor for the biological degradation of the chlorinated hydrocarbons. This test showed that the zero order reaction rate to be approximately $5x10^{-5}$ mmols/L-hr.

Fenton's Reagent was then injected to the shallow water-bearing zone. Ten wells (8 injection and 2 monitoring wells), installed in the area where the highest concentrations of VOCs were detected in groundwater, were used for delivery of the reagent to the subsurface. Follow-up groundwater sampling indicates that the use of Fenton's Reagent was successful for degradation of the chlorinated hydrocarbons detected in the groundwater. However, a rebound of chlorinated hydrocarbons was observed. The source of contaminant mass causing the rebound is presumably from the vadose zone, which was not targeted for treatment. Because of the shallow depth of the contamination the full thickness of the vadose zone could not be targeted for treatment. Attempts to treat the shallow soil may have resulted in surfacing of the Fenton's Reagent with little lateral distribution.

Bench-scale and field-scale tests were conducted for testing potassium permanganate as an in-situ chemical oxidant. Bench-scale tests were first conducted to estimate the permanganate uptake due to the natural organic material. These tests showed the soil present at FAA-B has a high oxidant demand.

Potassium permanganate was then injected to the saturated and unsaturated zones in areas showing the presence of chlorinated hydrocarbons in soil and/or groundwater, but outside the influence of the Fenton's reagent injection, to prevent interference between methods. Follow-up sampling showed that the permanganate had not migrated far from the injection point, in some cases was fully consumed within a foot of the injection points. A measurable decrease in total VOCs in groundwater was observed from samples collected after the injection of permanganate.

6.2 Conclusions

The following are the conclusions resulting from conducting the baseline characterization and the treatability studies:

- Contamination of groundwater and soil was delineated. The source area for groundwater contamination at FAA-B appears to correspond to soil contamination present in the area. Groundwater gradients and preferential pathways provided by the sand of the upper water bearing zone has assisted in the distribution of the contaminants. Soil contamination is limited to an area between the Facility 92 concrete pad and MW03.

- The contaminants identified include TCE, PCE, DCE, and VC.

- Injection of hydrogen appears to stimulate the anaerobic degradation of vinyl chloride and other chlorinated hydrocarbons present in the groundwater. Additional data are needed to determine if the rate is zero or first order with respect to hydrogen consumption.

- Fenton's Reagent will successfully degrade TCE and its degradation byproducts in groundwater.

- Uptake of potassium permanganate by the natural organic material appears to be a limiting factor in future application of this technology at FAA-B. The limited solubility (4 to 6 percent) of potassium permanganate makes delivery of the amounts required to provide for the natural organic uptake of material difficult.

- Groundwater samples collected in the close proximity of permanganate injection points indicated a measurable decrease of total VOCs in groundwater.

- Acetone and ketone were apparently generated during the Fenton's Reagent test. It is believed that this is a result of the reaction between the Fenton's reagent and natural of organic matter present in the subsurface.

- Additional actions may be necessary to remove the contaminated soil, which appears to be the source for groundwater contamination. This soil is too shallow for Fenton's reagent injection and has too high an oxidant demand for permanganate injection. Therefore, excavation of the soil may be the most prudent course of action.

- Post-injection sampling shows VOC contaminants to be present in groundwater at concentrations exceeding the maximum contaminant level, the remedial action goal for the WPAFB.

6.3 Future Actions

Based on the summary and conclusions presented above, future actions are required to achieve the remedial action goals at FAA-B. Specifically, concentrations of organic compounds in groundwater are to be less than the MCL. Post-test sampling shows that in-situ chemical oxidation is feasible for the destruction of chlorinated organics in the groundwater at FAA-B. However the presence of chlorinated organics in the vadose zone appears to be providing a continuing source of contamination to the groundwater. Remediation of this contamination needs to be part of the overall plan for additional action at FAA-B for achievement of the remediation goals.

Source removal is required in order to provide additional benefit towards remediation of the upper water-bearing zone. Source removal can be easily accomplished by excavation of contaminated soil down to the water bearing and disposed at an offsite landfill. The site would be backfilled with clean fill and restored to the original grade.

7.0 Investigation Derived Waste

Investigation and pilot test activities generated both liquid and solid wastes. Included in the waste stream were soil cuttings from soil borings and well installation activities, well purge water, well development water, and miscellaneous trash. Soil cuttings were placed in 55-gallon drums labeled and stored on site. Purge and development water was accumulated in a 210-gallon truck mounted storage tank. Each of the waste streams were then characterized for disposal based on the results of the sample analyses.

7.1 Water

A sample of the water collected in the 210-gallon storage tank was collected and submitted to the mobile lab for analysis. The analysis showed trace levels of organics (c-DCE 92 ppb, t-DCE 5.1 ppb, TCE 8.8 ppb, and VC 14 ppb). The lab data sheets are included in the Volume 2 of this report. These values were checked against levels permitted by the City of Dayton for WPAFB to dispose in the sanitary sewer.

7.2 Soil Cuttings

A composite sample of the soil cuttings was collected for characterization. The sample was submitted to a contract laboratory for TCLP (VOC) analysis. The results showed all VOCs below the method detection limit. The lab data sheets are included in the Volume 2 of this report. Provisions have been made to dispose of the soil as nonhazardous waste.

8.0 References

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TABLE 2-1
WELL LOCATIONS AND ELEVATIONS

Well	Coordinates (state plane) Northing	Easting	Top of Casing Elevation Feet - mean sea level	Screened Interval ft - bgs
Monitoring Well #3	653547.53	1553206.96	883.29	
Monitoring Well #7	653573.92	1553242.70	885.25	13-23
Monitoring Well #8	653466.02	1553192.75	881.38	22-32
Monitoring Well #9	653540.77	1553118.54	884.36	8-18
Injection Well #1	653585.59	1553240.13	885.68	14.2-18.2
Injection Well #2	653564.57	1553239.40	885.58	13.7-18.7
Injection Well #3	653576.86	1553248.43	885.65	14.2-18.2
Injection Well #4	653552.87	1553196.63	882.57	10.2-14.2
Injection Well #5	653553.15	1553214.27	883.60	11.1-16.1
Injection Well #6	653539.05	1553207.86	882.99	12.5-17.5
Injection Well #7	653562.10	1553222.80	885.09	13.2-17.2
Injection Well #8	653559.46	1553204.67	882.99	13-18

TABLE 2-2
SOIL ANALYTICAL RESULTS

Boring ID	**SB01**		**SB02**		**SB03**		**SB04**		**SB05**		**SB06**	
Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Depth	0-0.5'	4-8'	0-0.5'	4-8'	0-0.5'	4-8'	0-0.5'	4-8'	0-0.5'	0.5-4'	0-0.5'	0.5-4'
Date	28-Sep-99	28-Sep-99	28-Sep-99	28-Sep-99	28-Sep-99	28-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99
Detected Compounds (ppb)												
Vinyl Chloride	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Bromomethane	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
1,1-DCE	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Methylene Chloride	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Trans-1,2-DCE	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
1,1-DCA	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cis-1,2-DCE	<50	<50	<50	1100	<50	<50	<50	440	<50	<50	<50	<50
TCE	<50	<50	<50	<50	<50	260	<50	1000	<50	<50	<50	<50
PCE	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Acetone												
MEK												
Benzene	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Ethylbenzene	<50	<50	170	<50	<50	<50	180	<50	80	<50	<50	<50
Toluene	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Xylene	<150	<150	1950	<150	<150	<150	820	<150	350	<150	120	<150
Total VOCs	0	0	2120	1100	0	260	1000	1440	430	0	120	0

Notes:
* - Duplicate sample analyzed at a contract lab. All other samples analyzed by mobile lab, unless noted otherwise.

@ - Sample collected post oxidant injection. Analyzed at contract lab.

Mobile Lab used Method 5035 - Methanol sample preservation, resulting in 50:1 dilution

TABLE 2-2
SOIL ANALYTICAL RESULTS

Boring ID	SB07		SB08		SB09		SB10		SB11		SB12		
Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Depth	0-0.5'	0.5-4'	4-8'	8-12'	0-0.5'	0.5-4'	4-8'	8-12'	0.5-4'	4-8'	0-4'	4-8'	8-12'
Date	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	30-Sep-99	30-Sep-99	30-Sep-99	30-Sep-99	30-Sep-99	30-Sep-99	4-Oct-99	4-Oct-99	4-Oct-99
Detected Compounds (ppb)													
Vinyl Chloride	<100	<100	<1000	<1000	<100	<100	<100	<100	<100	<100	<100	<100	<100
Bromomethane	<250	<250	<2500	<2500	<250	<250	<250	<250	<250	<250	<250	<250	<250
1,1-DCE	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Methylene Chloride	<250	<250	<2500	<2500	<250	<250	<250	<250	<250	<250	<250	<250	<250
Trans-1,2-DCE	<50	<50	600	1100	<50	<50	220	<50	<50	<50	<50	<50	<50
1,1-DCA	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cis-1,2-DCE	<50	<50	69000	26000	<50	<50	1600	190	<50	<50	<50	<50	<50
TCE	<50	<50	<500	5600	<50	<50	<50	<50	<50	<50	<50	<50	<50
PCE	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Acetone													
MEK													
Benzene	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Ethylbenzene	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Toluene	<50	<50	<500	<500	<50	<50	<50	<50	<50	<50	<50	<50	<50
Xylene	<50	<150	<1500	<1500	<150	<150	<150	<150	<150	<150	<150	<150	<150
Total VOCs	0	0	69600	32700	0	0	1820	190	0	0	0	0	0

Notes:
* - Duplicate sample analyzed at a contract lab. All other samples analyzed by mobile lab, unless noted otherwise.

@ - Sample collected post oxidant injection. Analyzed at contract lab.

Mobile Lab used Method 5035 - Methanol sample preservation, resulting in 50:1 dilution

TABLE 2-2
SOIL ANALYTICAL RESULTS

Boring ID	SB13				SB14			SB15	SB16	SB17	SB18			
Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Depth	0-4'	4-8'	8-12'	20-22'	0-4'	4-8'	8-12'	8-12'	12-16'	12-16'	0-4'	4-8'	8-12'	12-16'
Date	4-Oct-99	4-Oct-99	4-Oct-99	4-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99
Detected Compounds (ppb)														
Vinyl Chloride	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Bromomethane	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
1,1-DCE	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Methylene Chloride	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250	<250
Trans-1,2-DCE	<50	<50	<50	73	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
1,1-DCA	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Cis-1,2-DCE	<50	<50	<50	270	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
TCE	<50	<50	<50	1800	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
PCE	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Acetone														
MEK														
Benzene	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Ethylbenzene	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Toluene	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Xylene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
Total VOCs	0	0	0	2143	0	0	0	0	0	0	0	0	0	0

Notes:
* - Duplicate sample analyzed at a contract lab. All other samples analyzed by mobile lab, unless noted otherwise.

@ - Sample collected post oxidant injection. Analyzed at contract lab.

Mobile Lab used Method 5035 - Methanol sample preservation, resulting in 50:1 dilution

TABLE 2-2
SOIL ANALYTICAL RESULTS

Boring ID	SB19				SB25@	SB26@	MW07		MW08		MW09		IN03			
Matrix	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil*	Soil	Soil*
Depth	0-4'	4-8'	8-12'	12-16'	20-22'	27'	4-8'	8-12'	0-4'	12-16'	4-8'	8-12'	4-8'	4-8'	8-12'	8-12'
Date	6-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	16-Feb-00	16-Feb-00	4-Oct-99	4-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	8-Oct-99	8-Oct-99	8-Oct-99	8-Oct-99
Detected Compounds (ppb)																
Vinyl Chloride	<100	<100	<100	<100	<2	<2	<392	<200	<100	<100	<100	<100	<100	<2	<100	<2
Bromomethane	<250	<250	<250	<250	<5	<5	<980	<500	<250	<250	<250	<250	<250	NA	<250	NA
1,1-DCE	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Methylene Chloride	<250	<250	<250	<250	<10	<10	<980	<500	<250	<250	<250	<250	<250	<10	<250	<10
Trans-1,2-DCE	<50	<50	<50	<50	<5	<5	<196	300	<50	<50	<50	<50	86	19.5	<50	11.7
1,1-DCA	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Cis-1,2-DCE	<50	<50	<50	<50	92.6	77.8	4100	2900	<50	<50	<50	<50	1000	95.1	480	147
TCE	<50	<50	<50	<50	287	5.6	33000	8400	<50	<50	<50	<50	1300	156	1300	590
PCE	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Acetone					<100	<100								<100		<100
MEK					<100	<100								<100		<100
Benzene	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Ethylbenzene	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Toluene	<50	<50	<50	<50	<5	<5	<196	<100	<50	<50	<50	<50	<50	<5	<50	<5
Xylene	<150	<150	<150	<150	<5	<5	<588	<300	<150	<150	<150	<150	<150	<5	<150	<5
Total VOCs	0	0	0	0	379.6	83.4	37100	11600	0	0	0	0	2386	270.6	1780	748.7

Notes:
* - Duplicate sample analyzed at a contract lab. All other samples analyzed by mobile lab, unless noted otherwise.

@ - Sample collected post oxidant injection. Analyzed at contract lab.

Mobile Lab used Method 5035 - Methanol sample preservation, resulting in 50:1 dilution

TABLE 2-2
SOIL ANALYTICAL RESULTS

Boring ID	IN05				IN06	IN07	IN08
Matrix	Soil	Soil*	Soil	Soil*	Soil	Soil	Soil
Depth	4-8'	4-8'	8-12'	8-12'	11'	10-12'	10-12'
Date	8-Oct-99	8-Oct-99	8-Oct-99	8-Oct-99	11-Oct-99	12-Oct-99	12-Oct-99
Detected Compounds (ppb)							
Vinyl Chloride	<100	<2	<100	<2	<100	<100	<100
Bromomethane	<250	NA	<250	NA	<250	<250	<250
1,1-DCE	<50	<5	<50	<5	<50	<50	<50
Methylene Chloride	<250	<10	<250	<10	<250	<250	<250
Trans-1,2-DCE	<50	<5	<50	<5	<50	<50	<50
1,1-DCA	<50	<5	<50	<5	<50	<50	<50
Cis-1,2-DCE	140	42.8	<100	11.1	<50	220	65
TCE	350	90.5	<50	<5	<50	200	<50
PCE	<50	<5	<50	<5	<50	<50	<50
Acetone		<100		<100			
MEK		<100		<100			
Benzene	<50	<5	<50	<5	<50	<50	<50
Ethylbenzene	<50	<5	<50	<5	<50	<50	<50
Toluene	<50	<5	<50	<5	<50	<50	<50
Xylene	<150	<5	<150	<5	<150	<150	<150
Total VOCs	490	133.3	0	11.1	0	420	65

Notes:
* - Duplicate sample analyzed at a contract lab. All other samples analyzed by mobile lab, unless noted otherwise.

@ - Sample collected post oxidant injection. Analyzed at contract lab.

Mobile Lab used Method 5035 - Methanol sample preservation, resulting in 50:1 dilution

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	SB01	SB02		SB03	SB04	SB05		SB06	SB07	SB08
Matrix	Water	Water	Water	Water	Water	Water	Water@	Water	Water	Water
Depth	10.3'	12-16'	20-24'	12-16'	12-16'	12-16'	12-16'	8-12'	8-12'	12-16'
Date	28-Sep-99	28-Sep-99	28-Sep-99	28-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99	29-Sep-99
Detected Compounds (ppb)										
Vinyl Chloride	82	58	26	10	36	7.9	8.5	2.2	30	21
Bromomethane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<25
1,1-DCE	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Methylene Chloride	<5	<5	<5	<5	<5	<5	<5	<5	<5	<25
Trans-1,2-DCE	1.9	<1	<1	<1	1.7	4.5	5.5	4.8	19	36
1,1-DCA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Cis-1,2-DCE	11	3.8	2.3	3.9	3.9	24	25	36	94	520
TCE	6.2	<1	<1	<1	<1	<1	<1	6.4	5	23
PCE	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MEK	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5
Xylene	<3	<3	<3	<3	<3	<3	<3	<3	<3	<15
Total VOCs	101.1	61.8	28.3	13.9	41.6	36.4	39	49.4	148	600

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	SB09	SB10	SB11	SB12	SB13	SB14			SB15	
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Depth	12-16'	12-16'	12-16'	12-16'	28'	14.1'	20'	26-28'	15-16'	27-28'
Date	30-Sep-99	30-Sep-99	30-Sep-99	4-Oct-99	4-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99	5-Oct-99
Detected Compounds (ppb)										
Vinyl Chloride	9.6	49	2.2	24	24	4.8	<2	<2	78	270
Bromomethane	<5	<25	<5	<5	<5	<25	<25	<25	<5	<5
1,1-DCE	<1	<5	<1	<1	<1	<5	<5	<5	<1	<1
Methylene Chloride	<5	<25	<5	<5	<5	<25	<25	<25	<5	<5
Trans-1,2-DCE	4	100	1.5	1.7	<1	<5	<5	<5	17	<1
1,1-DCA	<1	<5	<1	<1	<1	<5	<5	<5	79	<1
Cis-1,2-DCE	14	440	4.5	19	7.6	93	<1	<1	<1	240
TCE	<1	55	<1	<1	<1	280	<1	<1	<1	<1
PCE	<1	<5	<1	<1	<1	37	<1	<1	<1	<1
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MEK	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	<1	<5	<1	<1	<1	<5	<5	<5	<1	<1
Ethylbenzene	<1	<5	<1	<1	<1	<5	<5	<5	<1	<1
Toluene	<1	<5	<1	<1	<1	<5	<5	<5	<1	<1
Xylene	<3	<15	<3	<3	<3	<15	<15	<15	<3	<3
Total VOCs	27.6	644	8.2	44.7	31.6	414.8	0	0	174	510

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	SB16		SB17		SB18		SB19	MW01	MW02
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Depth	18-20'	26-28'	15-16'	24-25'	16-18'	23-28'	17'	22-27'	12-22'
Date	5-Oct-99	5-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	6-Oct-99	21-Oct-99	21-Oct-99
Detected Compounds (ppb)									
Vinyl Chloride	160	130	44	28	<2	<2	<2	59	27
Bromomethane	<50	<50	<5	<5	<5	<5	<5	<5	<5
1,1-DCE	<10	<10	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<50	<50	<5	<5	<5	<5	<5	<5	<5
Trans-1,2-DCE	14	<10	13	8.9	<1	<1	<1	5.8	7.2
1,1-DCA	<10	<10	<1	<1	<1	<1	<1	<1	<1
Cis-1,2-DCE	620	590	56	83	110	17	1.5	11	37
TCE	200	78	1.2	120	210	18	10	<1	<1
PCE	<10	<10	<1	<1	48	3.3	<1	<1	<1
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA
MEK	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	<10	<10	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<10	<10	<1	<1	<1	<1	<1	<1	<1
Toluene	<10	<10	<1	<1	<1	<1	<1	<1	<1
Xylene	<30	<30	<3	<3	<3	<3	<3	<3	<3
Total VOCs	994	798	114.2	239.9	368	38.3	11.5	75.8	71.2

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	MW03			MW04	MW05	MW07				
Matrix	Water	Water	Water	Water	Water	Water**	Water	Water*	Water	Water
Depth	8-13'	8-13'	8-13'	8-18'	9-19'	12-16'	13-23'	13-23'	13-23'	13-23'
Date	7-Oct-99	19-Oct-99	20-Oct-99	21-Oct-99	15-Nov-99	4-Oct-99	8-Oct-99	8-Oct-99	19-Oct-99	22-Oct-99
Detected Compounds (ppb)										
Vinyl Chloride	51	82	82	25	19.8	<200	23	12.1	29	25
Bromomethane	<5	<5	<5	<5	<5	<500	<5	<5	<5	<5
1,1-DCE	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Methylene Chloride	5.6	<5	<5	<5	<5	<500	<5	<5	<5	<5
Trans-1,2-DCE	2.1	1.4	1.5	2.5	6.1	<100	21	20.4	16	30
1,1-DCA	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Cis-1,2-DCE	35	4.3	3.8	14	30	2100	100	99.7	110	140
TCE	17	<1	<1	<1	<1	6100	19	19.7	9.7	7.9
PCE	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Acetone	NA	NA	NA	NA	<20	NA	NA	<20	NA	NA
MEK	NA	NA	NA	NA	<12.5	NA	NA	<12.5	NA	NA
Benzene	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<100	<1	<1	<1	<1
Xylene	<3	<3	<3	<3	<3	<300	<3	<1	<3	<3
Total VOCs	110.7	87.7	87.3	41.5	55.9	8200	163	151.9	164.7	202.9

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

** - Sample collected from an open borehole
These samples are not representative

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	MW08			MW09					
Matrix	Water#	Water	Water@	Water#	Water#	Water	Water*	Water	Water
Depth	27-27.5'	22-32'	22-32'	14'	20'	8-18'	8-18'	8-18'	8-18'
Date	5-Oct-99	21-Oct-99	21-Oct-99	6-Oct-99	6-Oct-99	8-Oct-99	8-Oct-99	21-Oct-99	27-Oct-99
Detected Compounds (ppb)									
Vinyl Chloride	29	32	33	48	34	32	18.9	60	19
Bromomethane	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,1-DCE	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<5	<5	<5	<5	<5	<5	<5	<5	<5
Trans-1,2-DCE	4.1	6.6	6.2	12	8.1	9.1	9	21	24
1,1-DCA	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cis-1,2-DCE	22	36	37	55	39	50	49.7	93	97
TCE	<1	<1	<1	1	<1	<1	<1	1.9	<1
PCE	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acetone	NA	NA	NA	NA	NA	NA	28.2	NA	39
MEK	NA	NA	NA	NA	NA	NA	<12.5	NA	<5
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	1.6	<1	<1	<1	<1	<1	<1	<1	<1
Xylene	<3	<3	<3	<3	<3	<3	<1	<3	<3
Total VOCs	56.7	74.6	76.2	116	81.1	91.1	105.8	175.9	179

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 2-3
GROUNDWATER ANALYTICAL RESULTS

Boring ID	IN03	IN05	IN06	IN08
Matrix	Water	Water	Water	Water
Depth	14-18'	12-14'	12'	14'
Date	21-Oct-99	8-Oct-99	11-Oct-99	12-Oct-99
Detected Compounds (ppb)				
Vinyl Chloride	4.9	300	47	180
Bromomethane	<5	<25	<5	<25
1,1-DCE	<1	<5	<1	<5
Methylene Chloride	<5	<25	<5	<25
Trans-1,2-DCE	15	<5	4.7	5.5
1,1-DCA	<1	<5	<1	<5
Cis-1,2-DCE	70	73	65	48
TCE	7.5	39	36	12
PCE	<1	<5	<1	<5
Acetone	<5	NA	NA	NA
MEK	<5	NA	NA	NA
Benzene	<1	<5	<1	<5
Ethylbenzene	<1	<5	<1	<5
Toluene	<1	<5	<1	<5
Xylene	<4	<15	<3	<15
Total VOCs	97.4	412	152.7	245.5

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 3-1
FENTON'S REAGENT INJECTION QUANTITIES

Injection Point	Injection Dates	Hydrogen Peroxide 25% Solution (gals)	Hydrogen Peroxide 50% Solution (gals)	Ferrous Sulfate 100 ppm Solution (gals)
Injection Well #1	26-Oct and 28-Oct	26.90	155.30	364.4
Injection Well #2	27-Oct, 28-Oct, and 29-Oct	33.90	125.75	319.3
Injection Well #3	26-Oct and 27-Oct	210.65	0.00	421.3
Injection Well #4	26-Oct, 27-Oct, and 28-Oct	156.10	205.55	723.3
Injection Well #5	27-Oct and 28-Oct	77.90	219.80	595.4
Injection Well #6	26-Oct, 27-Oct, 28-Oct, and 29-Oct	263.55	157.50	842.1
Injection Well #7	26-Oct and 27-Oct	145.95	0.00	291.9
Injection Well #8	27-Oct, 28-Oct, and 29-Oct	172.65	157.50	660.3
Monitoring Well #3	29-Oct	0.00	81.75	163.5
Monitoring Well #7	28-Oct	0.00	117.30	234.6
	Total Volume Injected (gals):	**1087.60**	**1220.45**	**4616.10**

TABLE 3-2
PRE- AND POST-TEST INJECTION ANALYSES - FENTON'S REAGENT

Boring ID	MW03								
	Pre-injection			During Injection			Post-Injection		
Matrix	Water	Water	Water	Water	Water	Water	Water*	Water*	Water*
Depth	8-13'	8-13'	8-13'	8-13'	8-13'	8-13'	8-13'	8-13'	8-13'
Date	7-Oct-99	19-Oct-99	20-Oct-99	27-Oct-99	28-Oct-99	29-Oct-99	1-Nov-99	15-Nov-99	15-Dec-99
Detected Compounds (ppb)									
Vinyl Chloride	51	82	82	2.4	<2	<2	<2	24.2	49
Bromomethane	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,1-DCE	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	5.6	<5	<5	<5	<5	<5	<5	<5	<5
Trans-1,2-DCE	2.1	1.4	1.5	1.5	3.5	<1	<1	4.4	5.2
1,1-DCA	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cis-1,2-DCE	35	4.3	3.8	29	52	7.7	47	33.3	30.7
TCE	17	<1	<1	12	13	3.1	31.8	13.5	4.4
PCE	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acetone	NA	NA	NA	<5	<5	780	1730	120	<20
MEK	NA	NA	NA	<5	<5	14	<62	<12.5	<12.5
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1
Xylene	<3	<3	<3	<3	<3	<3	<3	<1	<1
Total VOCs	110.7	87.7	87.3	44.9	68.5	804.8	1808.8	195.4	89.3

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 3-2
PRE- AND POST-TEST INJECTION ANALYSES - FENTON'S REAGENT

Boring ID	MW07									
	Pre-injection				During Injection			Post-Injection		
Matrix	Water	Water*	Water	Water	Water	Water	Water	Water*	Water*	Water*
Depth	13-23'	13-23'	13-23'	13-23'	13-23'	13-23'	13-23'	13-23'	13-23'	13-23'
Date	8-Oct-99	8-Oct-99	19-Oct-99	22-Oct-99	27-Oct-99	28-Oct-99	29-Oct-99	1-Nov-99	15-Nov-99	15-Dec-99
Detected Compounds (ppb)										
Vinyl Chloride	23	12.1	29	25	<2	<20	<2	<2	4.9	5.4
Bromomethane	<5	<5	<5	<5	<5	<50	<5	<5	<5	<5
1,1-DCE	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Methylene Chloride	<5	<5	<5	<5	<5	<50	<5	<5	<5	<5
Trans-1,2-DCE	21	20.4	16	30	11	54	<1	<1	35.6	43.6
1,1-DCA	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Cis-1,2-DCE	100	99.7	110	140	97	560	4.5	54.8	765	393
TCE	19	19.7	9.7	7.9	82	82	6.6	54.8	630	61.7
PCE	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Acetone	NA	<20	NA	NA	<5	<50	320	986	259	<20
MEK	NA	<12.5	NA	NA	<5	<50	6.8	122	<12.5	<12.5
Benzene	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<10	<1	<1	<1	<1
Xylene	<3	<1	<3	<3	<3	<30	<3	<3	<3	<3
Total VOCs	163	151.9	164.7	202.9	190	696	337.9	1217.6	1694.5	503.7

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 3-2
PRE- AND POST-TEST INJECTION ANALYSES - FENTON'S REAGENT

Boring ID	SB02	IN07		SB10	IN01	
	Pre-Injection	Post Injection		Pre-Injection	Post-Injection	
Matrix	Water	Water*	Water*	Water	Water	Water*
Depth	12-16'	12-14'	12-14'	12-16'	14'	14'
Date	28-Sep-99	1-Nov-99	15-Dec-99	30-Sep-99	15-Nov-99	15-Dec-99
Detected Compounds (ppb)						
Vinyl Chloride	58	<5	71.9	49	<5	12.9
Bromomethane	<5	<25	<25	<25	<25	<25
1,1-DCE	<1	<5	<5	<5	<5	<5
Methylene Chloride	<5	<25	<25	<25	<25	<25
Trans-1,2-DCE	<1	9.5	23.8	100	12.4	26.1
1,1-DCA	<1	<5	<5	<5	<5	<5
Cis-1,2-DCE	3.8	80	223	440	71.4	141
TCE	<1	15	6.8	55	11	3.1
PCE	<1	<5	<5	<5	<5	<5
Acetone	NA	620	28.9	NA	1820	<20
MEK	NA	62	<12.5	NA	526	<12.5
Benzene	<1	<5	<5	<5	<5	<5
Ethylbenzene	<1	<5	<5	<5	<5	<5
Toluene	<1	<5	<5	<5	<5	<5
Xylene	<3	<5	<5	<15	<15	<15
Total VOCs	61.8	786.5	354.4	644	2440.8	183.1

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen
NA - Not Analyzed

TABLE 4-1

ANALYTICAL RESULTS FOR OXIDANT DEMAND TEST

Contaminant	Matrix	Units	Volume of Potassium Permanganate Added 0 mL	7 ml	8 ml	9 ml	10 ml
trans-1,2-DCE	Soil	μg/kg	300	ND	ND	ND	ND
cis-1,2-DCE	Soil	μg/kg	2900	ND	ND	ND	ND
TCE	Soil	μg/kg	8400	75	100	ND	ND
Acetone	Groundwater	μg/L	ND	70	52	71	ND

ND – Non-detect

Note: For cross reference to lab data sheets (Appendix F) sample IDs for these samples are coded as follows:

Sample ID T-1-#-M

Where:
T Titration Test
4 – 7 mL permanganate added
5 – 8 mL permanganate added
6 – 9 mL permanganate added
7 – 10 mL permanganate added

M Matrix (S - soil, W - water)

Example: T-1-6-S Soil sample, 9 mL permanganate added

TABLE 4-2

INITIAL SOIL AND GROUNDWATER CONTAMINATION

Contaminant	MW03 Groundwater (µg/L)	MW07 Soil (µg/kg)
Sample ID	MW-3 Bench Test	WP-S11-SS02-MW07
Vinyl Chloride	51	ND
Methylene Chloride	5.16	ND
Trans-1,2-DCE	2.1	300
Cis-1,2-DCE	35	2900
TCE	17	8400

TABLE 4-3

SUMMARY OF RESULTS FOR SLURRY PERMANGANATE TEST

				Stoichiometric Potassium Permanganate			
Parameter	**Matrix**	**Time (hours)**	**Control Not Quenched**	**Control Quenched**	**3x**	**7x**	**15x**
Sample ID					R-1-3-T-M*	R-1-7-T-M	R-1-15-T-M
ORP (mV)	Slurry	0		305	NS	NS	NS
		4		NS	385	625	650
		8		NS	315	535	625
		24		315	325	370	390
Vinyl Chloride (µg/L)	Water	0	<2	<2	NS	NS	NS
		4	NS	NS	<2	<2	<2
		8	NS	NS	<2	<2	<2
		24	<2	<2	<2	<2	<2
trans-1,2-DCE (µg/L)	Water	0	<1	<1	NS	NS	NS
		4	NS	NS	<1	<1	<1
		8	NS	NS	<1	<1	<1
		24	<1	<1	<1	<1	<1
cis-1,2-DCE (µg/L)	Water	0	51	51	NS	NS	NS
		4	NS	NS	25	29	24
		8	NS	NS	36	24	46
		24	53	31	36	25	31
TCE (µg/L)	Water	0	200	200	NS	NS	NS
		4	NS	NS	69	89	59
		8	NS	NS	138	78	71
		24	84	51	79	57	70
Acetone (µg/L)	Water	0	<5	<5	NS	NS	NS
		4	NS	NS	33	<5	<5
		8	NS	NS	<5	<5	<5
		24	<5	<5	<5	<5	<5
cis-1,2-DCE (µg/kg)	Soil	0	56	56	NS	NS	NS
		4	NS	NS	<50	<50	76
		8	NS	NS	82	<50	56
		24	<50	<50	<50	100	<50
TCE (µg/kg)	Soil	0	630	630	NS	NS	NS
		4	NS	NS	650	610	440
		8	NS	NS	850	270	470
		24	290	300	290	370	330

NS – Not Sampled. Sample was not sacrificed at the given time as per the work plan.

* - Sample ID Key R-1-S-T-M: R – Rate Test, S – stochiometric quantity (0, 3,7,15), T – Time (0,4,8,24), M – Matrix (w - water, s - soil) – See Appendix F for the Lab data sheets

TABLE 4-4
PERMANGANATE INJECTION QUANTITIES

Injection Point	Injection Intervals Feet below ground surface	2% $KMnO_4$ Gallons	$KMnO_4$ lbs
PI01	28-32', 18-22', 14-18'	160	27
PI02	12-16', 16-20', 23-27'	240	40
PI03	10-14', 19-23', 23-27'	240	40
PI04	10-14', 18-22', 22-26'	240	40
PI05	10-14', 18-22', 22-26'	240	40
PI06	10-14', 18-22', 22-26'	240	40
PI07	6-10', 10-14', 18-22'	240	40
PI08	10-14', 15-19', 21-25'	240	40
PI09	12-16', 16-20', 21-25'	240	40
PI10	10-14'	80	13
PI11	4-8', 8-12', 12-16'	240	40
PI12	4-8', 8-12', 12-16'	240	40
PI13	8-12', 14-18'	160	27
PI14	8-12'	80	13
PI15	8-12'	80	13
PI16	8-12'	80	13
PI17	8-12'	80	13
PI18	4-8', 12-16'	160	27
PI19	8-12'	80	13
PI20	8-12'	80	13
PI21	8-12'	80	13
PI22	8-12'	80	13
PI23	22-26', 26-30'	160	27
PI24	22-26', 26-30'	160	27
PI25	12-16'	80	13
PI26	21-25', 25-29'	160	27
PI27	22-26', 26-30'	160	27
PI28	22-26', 26-30'	160	27
PI29	8-12'	80	13
PI30	8-12'	80	13
PI31	8-12'	80	13
PI32	22-26', 26-30'	160	27
PI33	22-26', 26-30'	160	27
	Total Material Injected	**5040 gal**	**841**

TABLE 4-5
PRE- AND POST-TEST INJECTION SAMPLING - POTASSIUM PERMANGANATE

Boring ID	MW08					MW09							
	Pre-Injection			Post-Injection		Pre-Injection						Post-Injection	
Matrix	Water#	Water	Water@	Water*	Water*	Water#	Water#	Water	Water*	Water	Water	Water*	Water*
Depth	27-27.5'	22-32'	22-32'	22-32'	22-32'	14'	20'	8-18'	8-18'	8-18'	8-18'	8-18'	8-18'
Date	5-Oct-99	21-Oct-99	21-Oct-99	15-Nov-99	15-Dec-99	6-Oct-99	6-Oct-99	8-Oct-99	8-Oct-99	21-Oct-99	27-Oct-99	15-Nov-99	15-Dec-99
Detected Compounds (ppb)													
Vinyl Chloride	29	32	33	<1	17.7	48	34	32	18.9	60	19	11.1	11.3
Bromomethane	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
1,1-DCE	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methylene Chloride	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Trans-1,2-DCE	4.1	6.6	6.2	<1	4.4	12	8.1	9.1	9	21	24	9.5	8
1,1-DCA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cis-1,2-DCE	22	36	37	<1	28.6	55	39	50	49.7	93	97	49.5	42.2
TCE	<1	<1	<1	<1	<1	1	<1	<1	<1	1.9	<1	<1	<1
PCE	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acetone					<20				28.2		39	31.4	<20
MEK					<12.5				<12.5		<5	<5	<12.5
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	1.6	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Xylene	<3	<3	<3	<3	<3	<3	<3	<3	<1	<3	<3	<3	<3
Total VOCs	56.7	74.6	76.2	0	50.7	116	81.1	91.1	105.8	175.9	179	101.5	61.5

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen

TABLE 4-5
PRE- AND POST-TEST INJECTION SAMPLING - POTASSIUM PERMANGANATE

Boring ID	SB-18	SB-20	SB07	SB21	SB22	SB16	SB23	SB13	SB25
	Pre-Injection	Post-Injection	Pre-Injection	Post-Injection		Pre-Injection	Post-Injection	Pre-Injection	Post-Injection
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water
Depth	16-18'	16-20'	8-12'	9-13'	9-13'	18-20'	19-23'	28'	25-29'
Date	6-Oct-99	16-Feb-00	29-Sep-99	16-Feb-00	16-Feb-00	5-Oct-99	16-Feb-00	4-Oct-99	16-Feb-00
Detected Compounds (ppb)									
Vinyl Chloride	<2	1.3	30	29.2	9.5	160	17.1	24	132
Bromomethane	<5	<1	<5	<1	<1	<50	<1	<5	<1
1,1-DCE	<1	<1	<1	<1	<1	<10	<1	<1	4.2
Methylene Chloride	<5	<5	<5	<5	<5	<50	<5	<5	<5
Trans-1,2-DCE	<1	<1	19	5.2	6.2	14	5.6	<1	3.6
1,1-DCA	<1	<1	<1	<1	<1	<10	<1	<1	<1
Cis-1,2-DCE	110	79.9	94	27.4	33.3	620	173	7.6	542
TCE	210	75.8	5	10.6	7.5	200	73.1	<1	382
PCE	48	2	<1	<1	<1	<10	<1	<1	<1
Acetone	NA	<10	NA	<10	<10	NA	<10	NA	<10
MEK	NA	<10	NA	<10	<10	NA	<10	NA	<10
Benzene	<1	<1	<1	<1	<1	<10	<1	<1	1.4
Ethylbenzene	<1	<1	<1	<1	<1	<10	<1	<1	<1
Toluene	<1	2.2	<1	<1	1.1	<10	1.3	<1	<1
Xylene	<3	1.4	<3	<1	<1	<30	<1	<3	<1
Total VOCs	368	162.6	148	72.4	57.6	994	270.1	31.6	1065.2

Notes:
All SB samples collected using a GeoProbe microscreen
@ - Duplicate sample
* - Duplicate sample analyzed at a contract lab
# - Sampled from an open borehole prior to setting the well screen

TABLE 5-1
HYDROGEN TEST DATA

Date & Time	Volume pumped gallons	SF6 mg/L	H2 mg/L
10/21/99 8:17		17	0.2320
10/22/99 8:45	3.00	0.900	0.0278
8:51	4.00	1.480	0.0274
8:58	5.17	1.500	0.0165
9:06	6.51	1.540	0.0072
9:11	7.34	1.240	0.0034
9:17	8.34	0.940	0.0039
9:23	9.35	1.280	0.0042
9:29	10.35	1.240	0.0029
9:35	11.35	1.660	0.0046
9:41	12.35	1.600	0.0056
9:47	13.35	1.590	0.0067
9:53	14.36	1.480	0.0040
9:59	15.36	1.360	0.0045
10:03	16.03	1.760	0.0072
10:09	17.03	1.260	0.0056
10:15	18.03	1.480	0.0055
10:21	19.03	1.480	0.0045
10:27	20.03	1.560	0.0036
10:33	21.04	1.280	0.0040
10:39	22.04	0.260	0.0058
10:45	23.04	0.780	0.0039
10:51	24.04	0.740	0.0047
10:57	25.04	0.340	0.0029
11:03	26.05	0.630	0.0076
11:09	27.05	0.960	0.0025
11:15	28.05	0.240	0.0043
11:21	29.05	0.128	0.0027
11:27	30.05	0.120	0.0028
11:33	31.06	0.110	0.0018
11:39	32.06	0.106	0.0013
11:45	33.06	0.092	0.0015
11:51	34.06	0.172	0.0016
11:57	35.06	0.160	0.0020
12:03	36.07	0.144	0.0009
12:09	37.07	0.140	0.0013
12:15	38.07	0.144	0.0021
12:21	39.07	0.130	0.0020
12:27	40.07	0.132	0.0018
12:33	41.08	0.126	0.0023
12:39	42.08	0.136	0.0022
12:45	43.08	0.120	0.0018

TABLE 5-1
HYDROGEN TEST DATA

Date & Time	Volume pumped gallons	SF6 mg/L	H2 mg/L
12:51	44.08	0.110	0.0023
12:57	45.08	0.136	0.0016
13:15	48.09	0.128	0.0015
13:27	50.09	0.092	0.0015
13:39	52.10	0.102	0.0015
13:51	54.10	0.092	0.0009
14:03	56.11	0.088	0.0009
14:15	58.11	0.104	0.0011
14:27	60.11	0.098	0.0014
14:39	62.12	0.112	0.0021
14:51	64.12	0.110	0.0015
15:03	66.13	0.060	0.0005
15:15	68.13	0.072	0.0011
15:27	70.13	0.080	0.0004
15:39	72.14	0.084	0.0005
15:51	74.14	0.018	0.0010
16:03	76.15	0.104	0.0005
16:15	78.15	0.108	0.0012
16:27	80.15	0.100	0.0012
16:39	82.16	0.094	0.0008

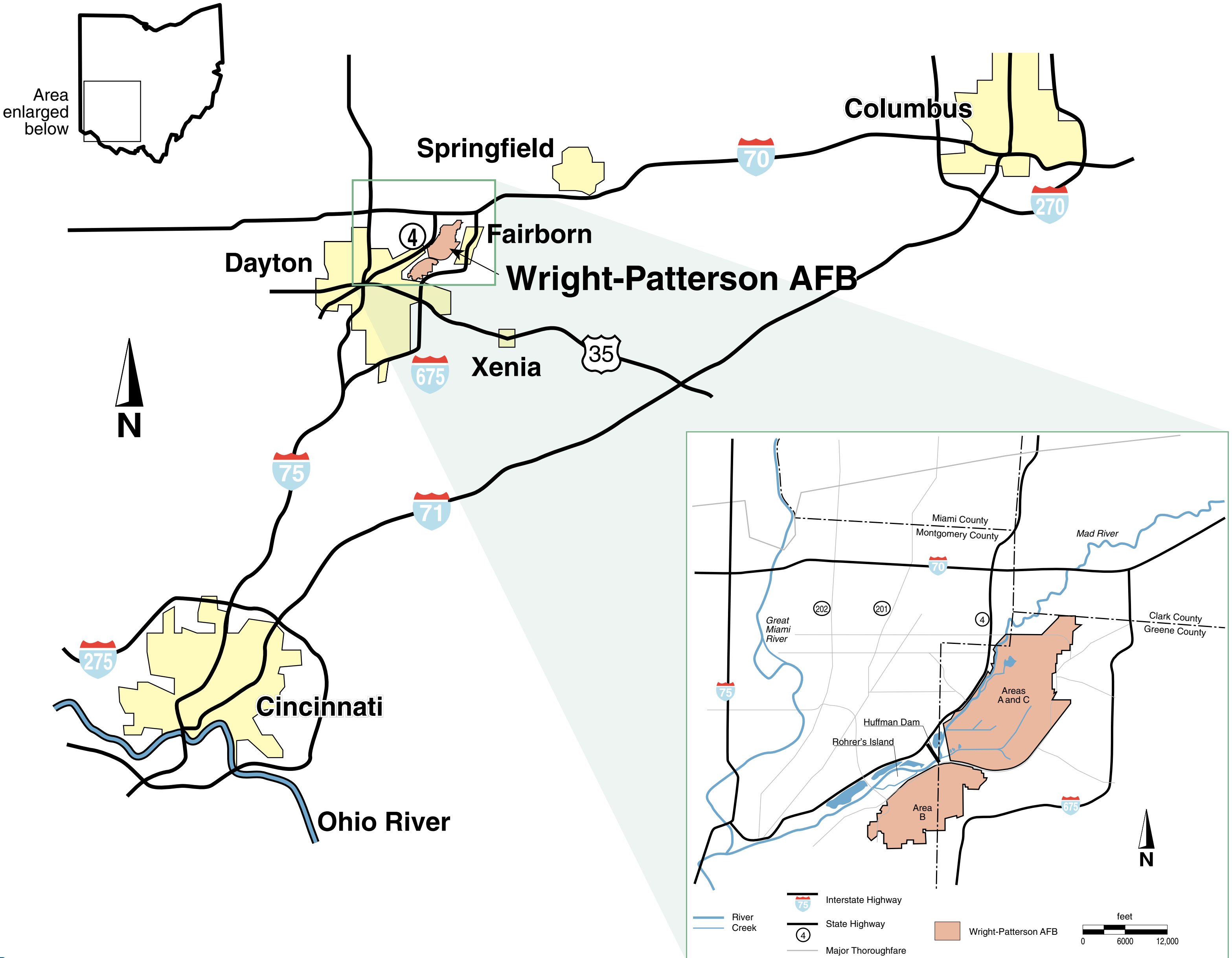

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Figure 1-1. Area Location Map.

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	5/17/99	APPROVED BY			K-781791-0201-5/99-w

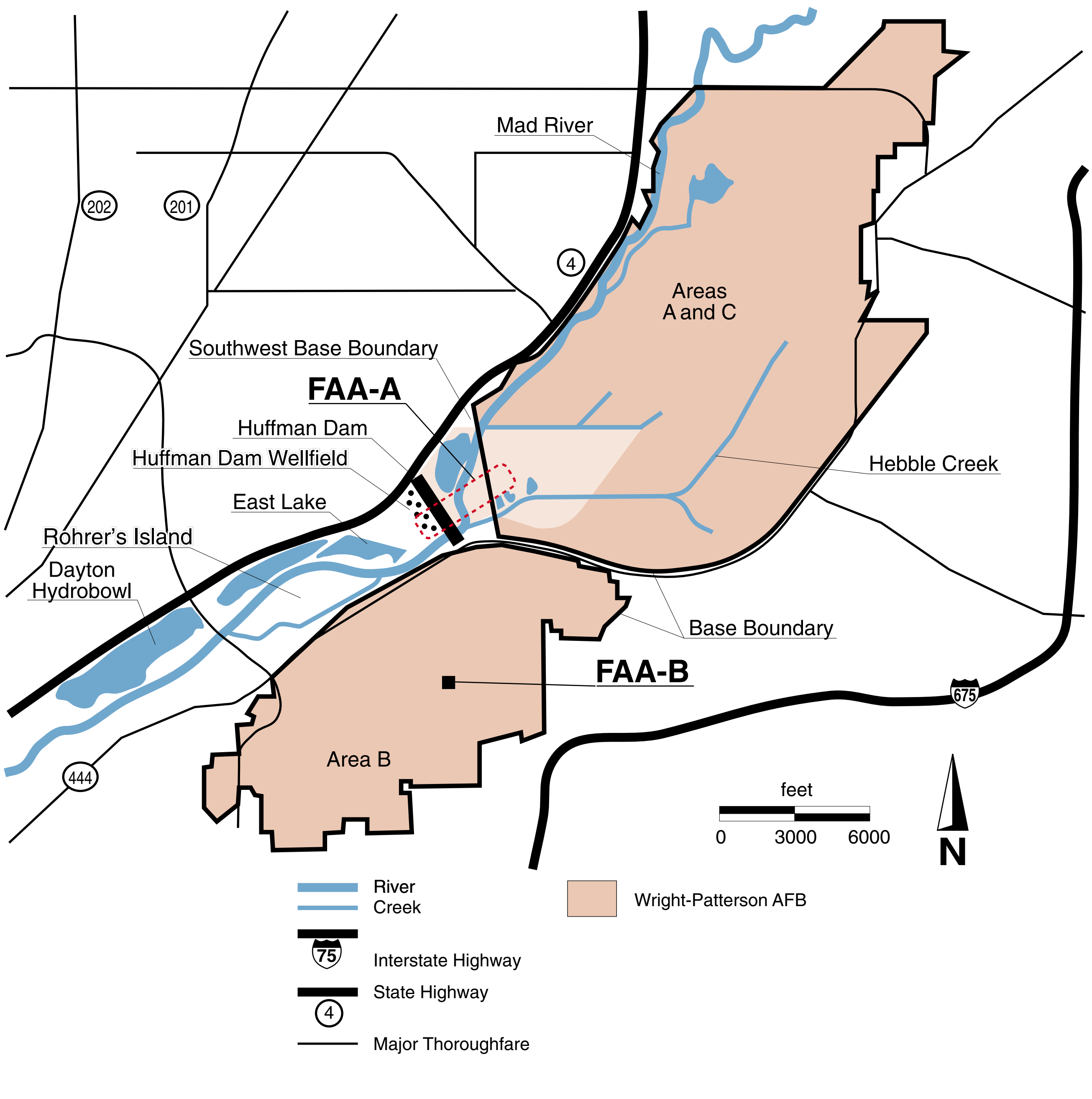

Figure 1-2. FAA-A and FAA-B relative to WPAFB and vicinity.

DRAWING NO. K-781791-0201-5/99-w

CHECKED BY

APPROVED BY

KMS 5/17/99

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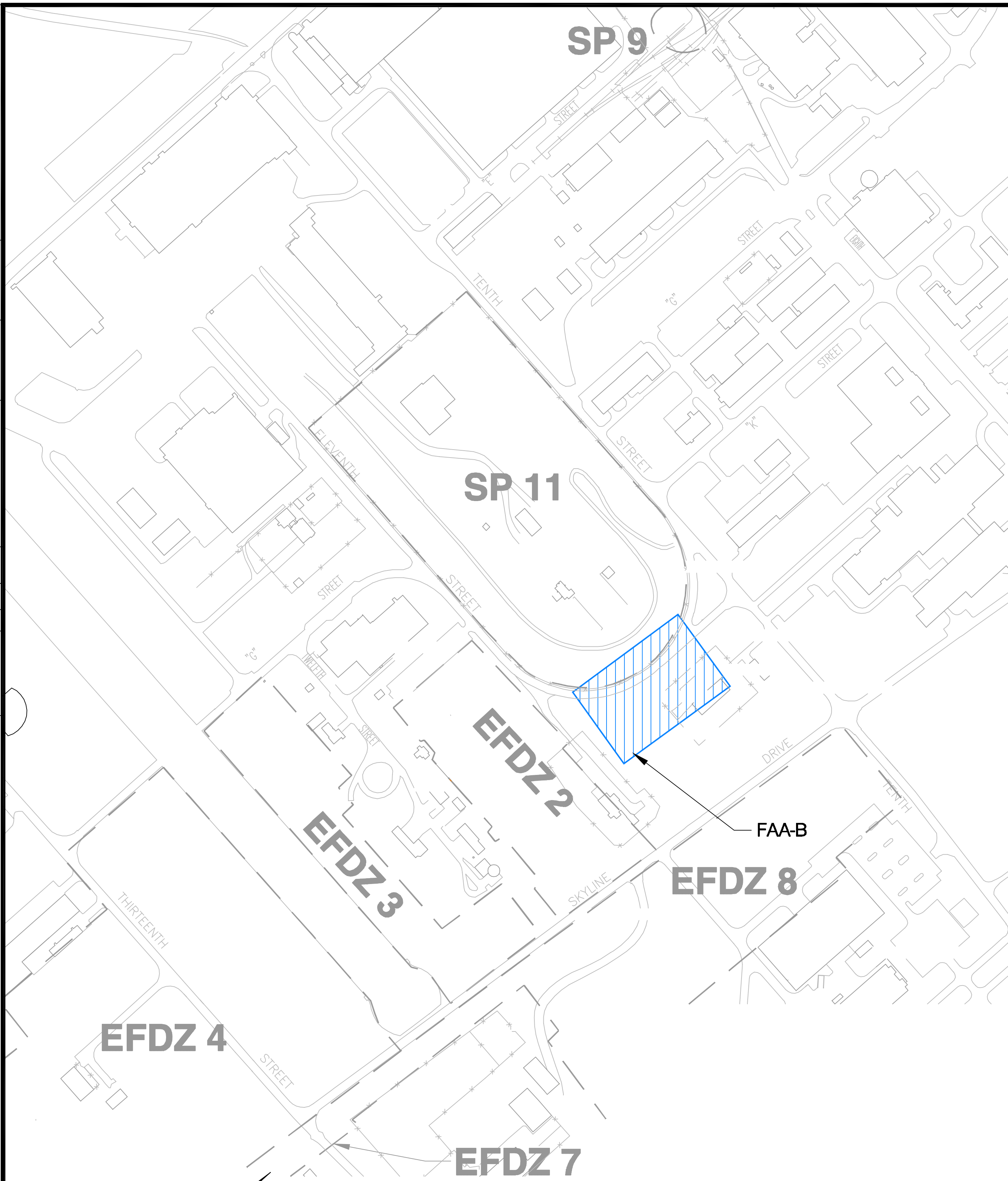

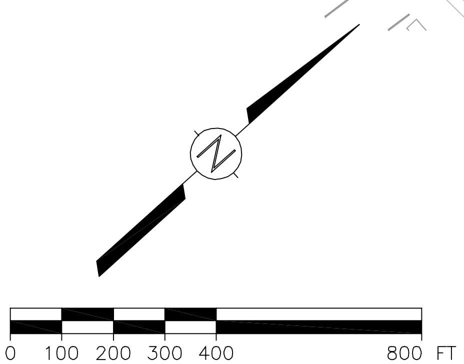

Figure 1-3
Site Layout

INTERNATIONAL
TECHNOLOGY
CORPORATION

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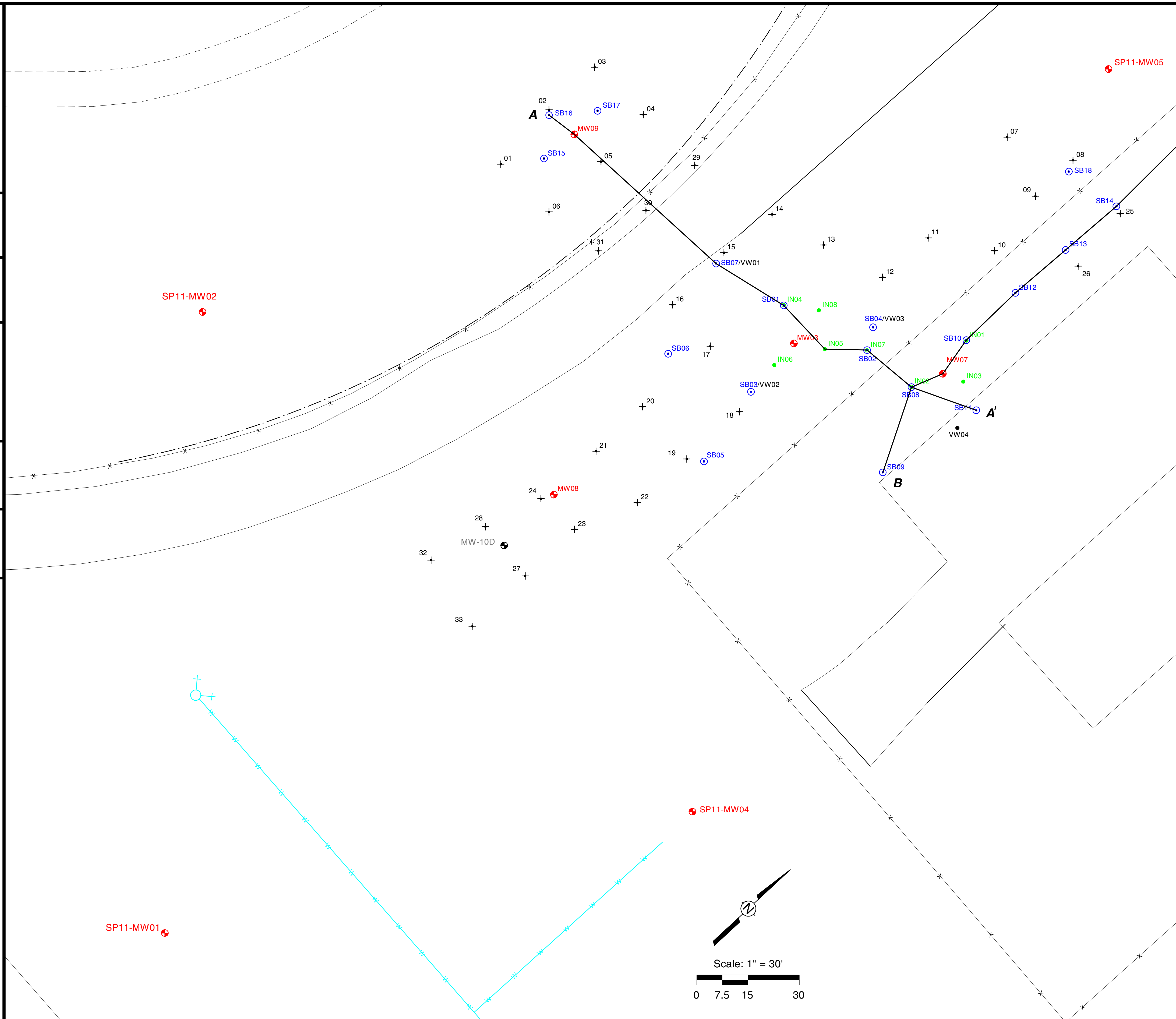

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT

IN FENTON'S REAGENT INJECTION WELL
SB SOIL BORING
VW VENT WELL
MW MONITORING WELL
(ND) NOT DETECTED
NOTE: MW-10D HAS BEEN ABANDONED

Figure 2-1.
BASE MAP

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DATE 11/16/99
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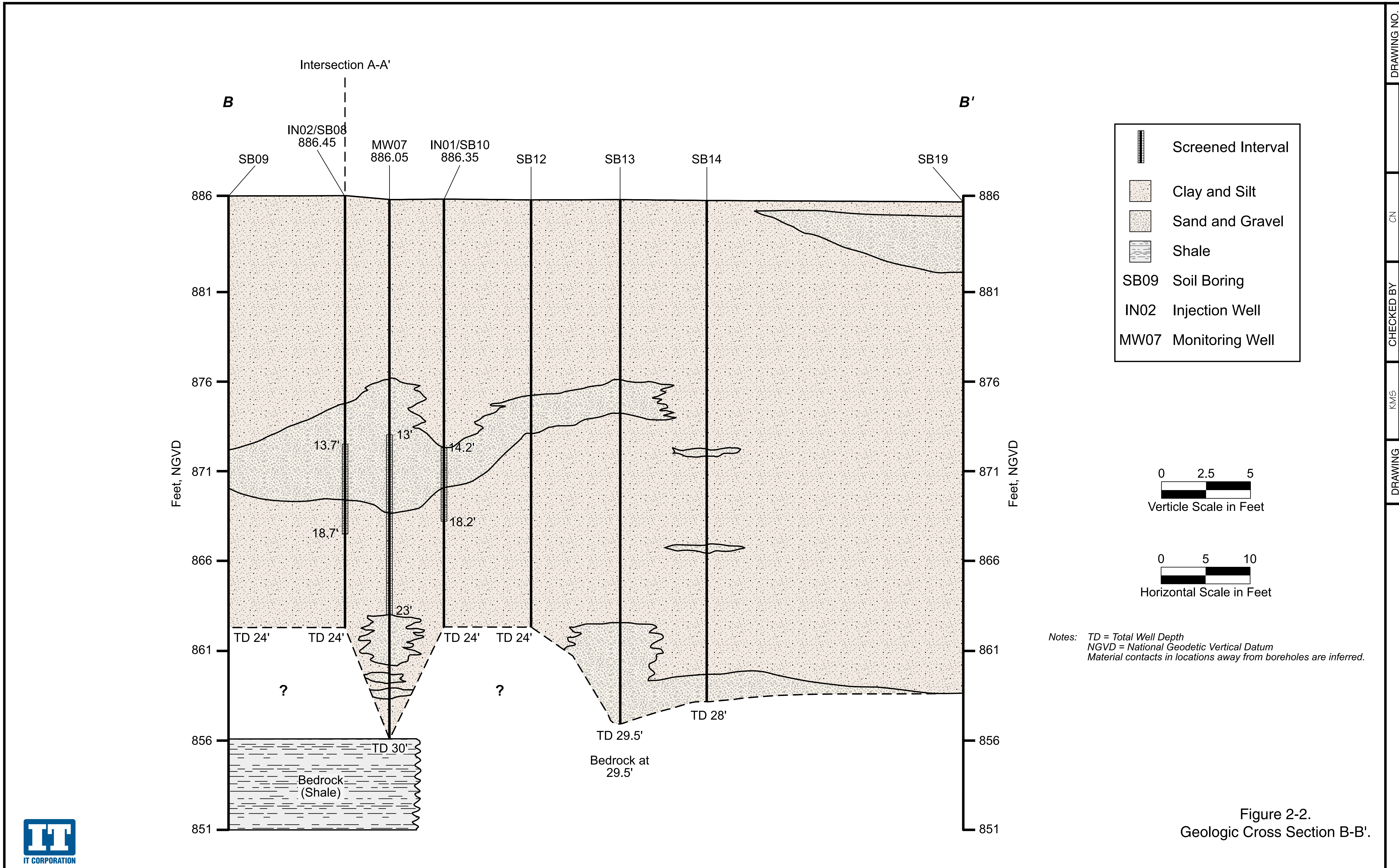
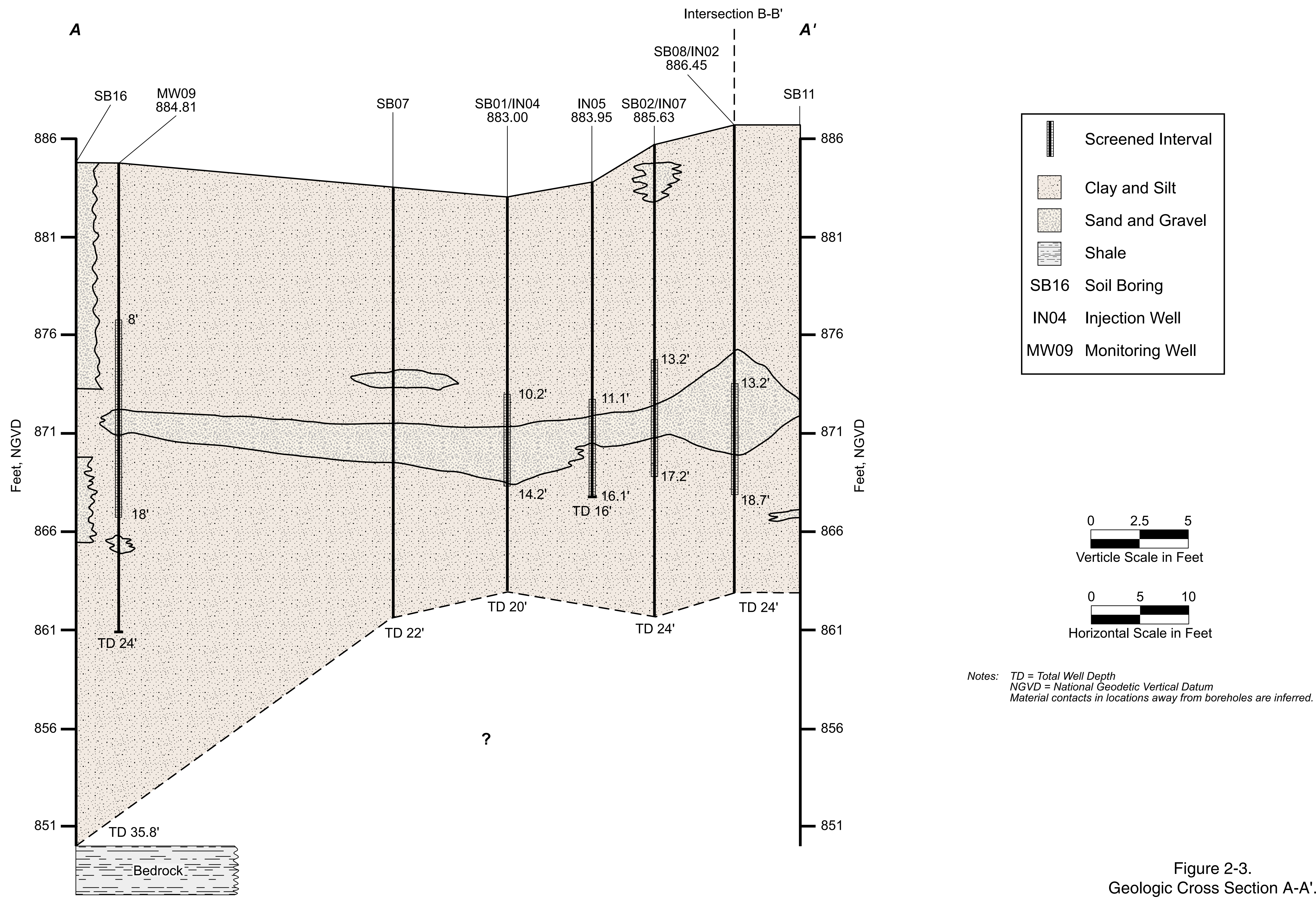


Figure 2-2.
Geologic Cross Section B-B'.



Notes: *TD = Total Well Depth*
NGVD = National Geodetic Vertical Datum
Material contacts in locations away from boreholes are inferred.

Figure 2-3.
Geologic Cross Section A-A'.

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APPROVED BY RS

DRAWING BY KMS 4/19/00

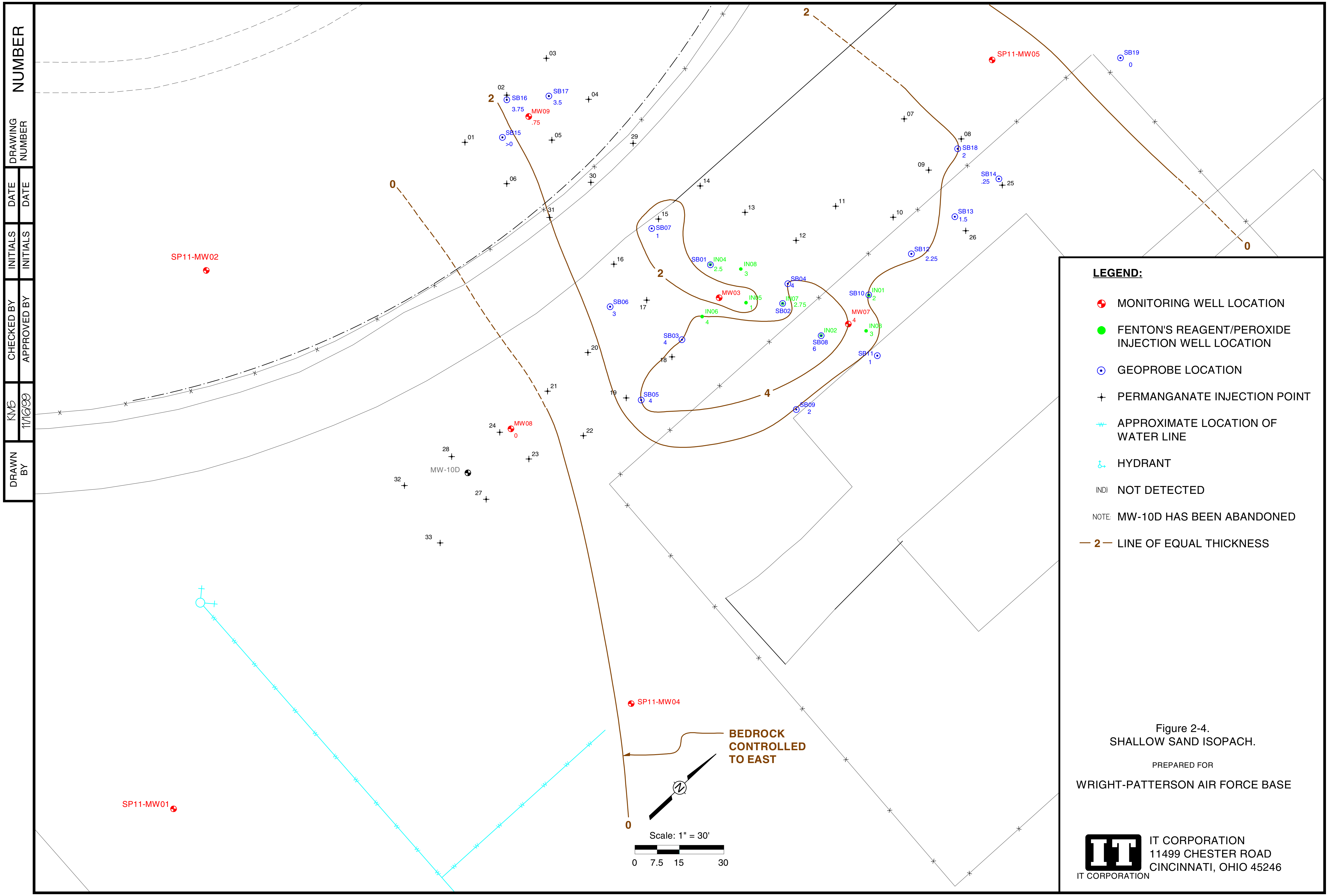
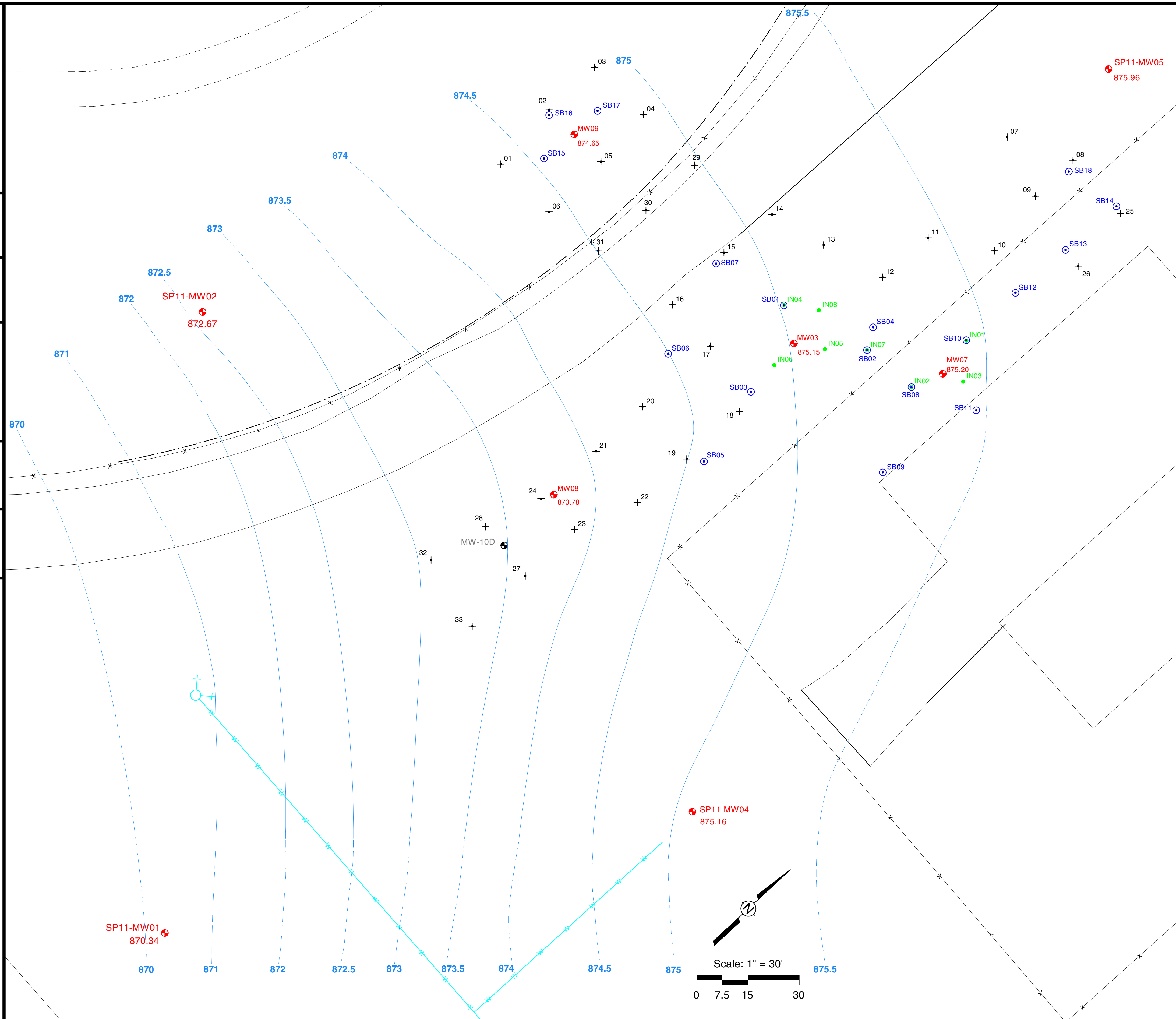


Figure 2-4.
SHALLOW SAND ISOPACH.



LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- (ND) NOT DETECTED
- NOTE: MW-10D HAS BEEN ABANDONED
- 870 POTENTIOMETRIC SURFACE ELEVATION , FT MSL DASHED WHERE INFERRED

Figure 2-5.
POTENTIOMETRIC SURFACE MAP
MARCH 2000.

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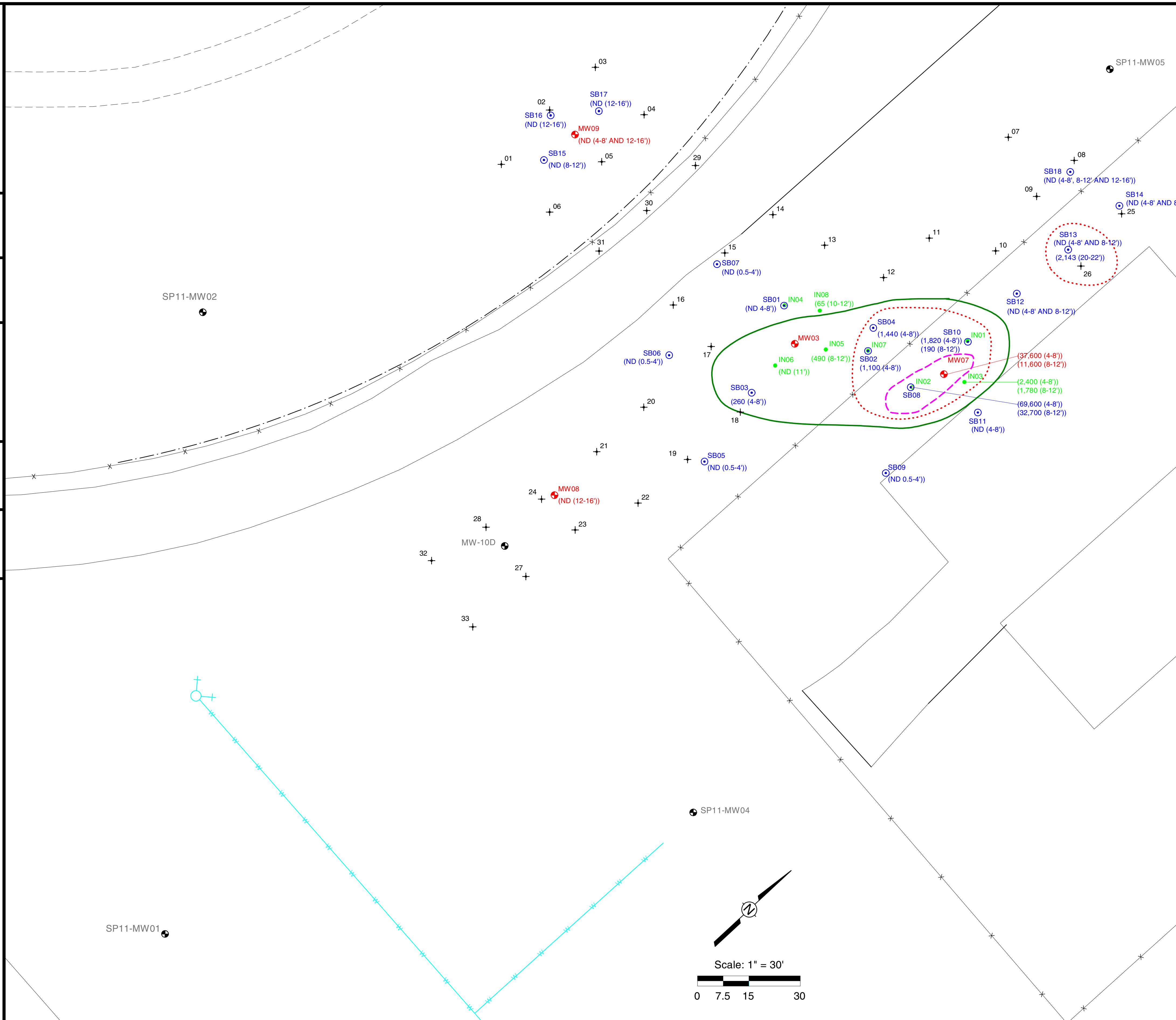

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- 10,000 µg/kg TOTAL VOC
- 1,000 µg/kg TOTAL VOC
- 100 µg/kg TOTAL VOC
- (1,500 (4-8')) TOTAL VOC IN SOIL (CONCENTRATION (µg/kg) AND DEPTH IN FEET BELOW GROUNDSURFACE
- (ND) NOT DETECTED
- NOTE: MW-10D HAS BEEN ABANDONED

Figure 2-6.
BASELINE INVESTIGATION
TOTAL VOC CONCENTRATION
IN SOIL.

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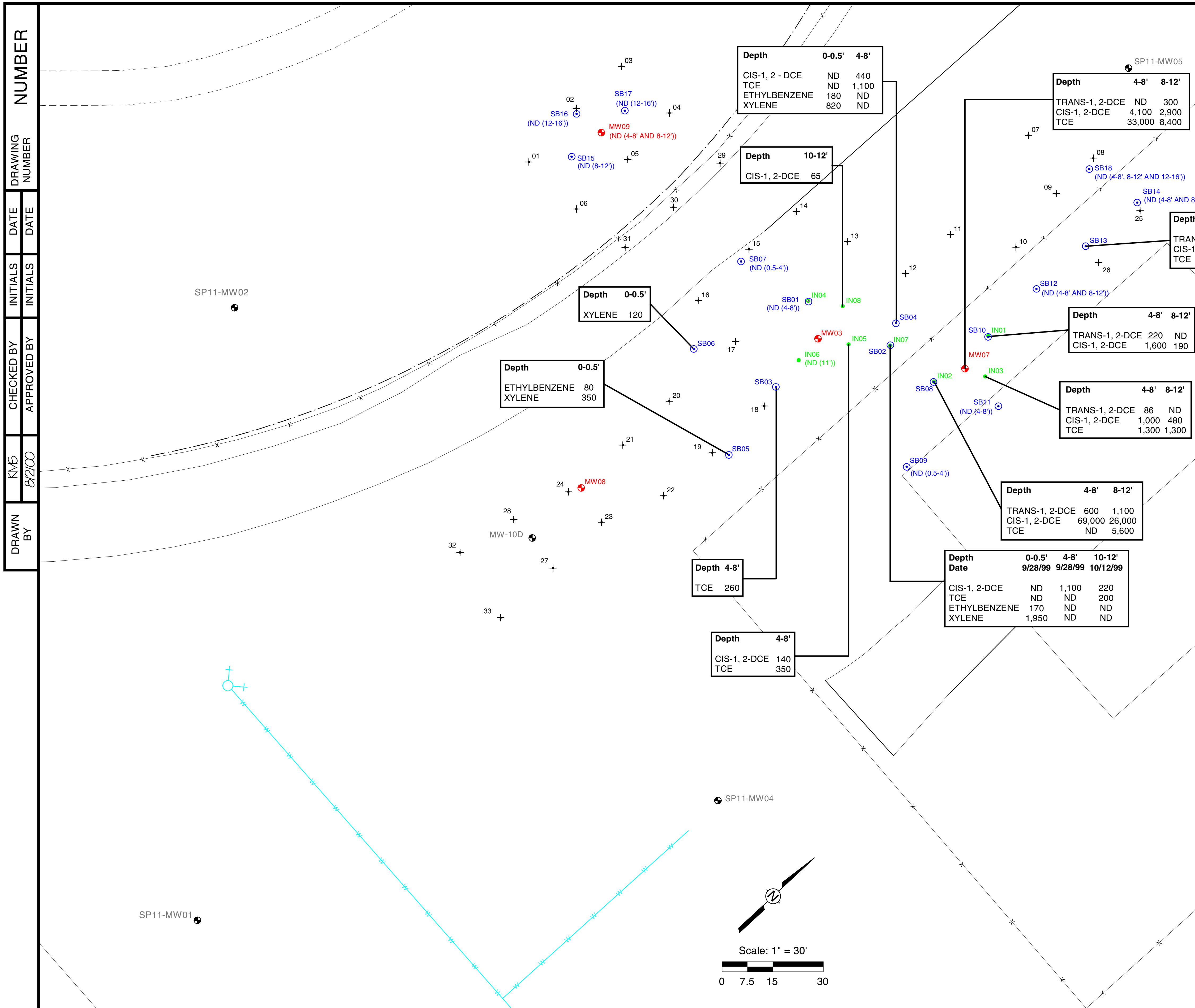

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- (ND) NOT DETECTED
- NOTE: MW-10D HAS BEEN ABANDONED
- ALL CONCENTRATIONS IN µg/kg

Figure 2-7.
BASELINE INVESTIGATION
SOIL CONTAMINANT
CONCENTRATIONS

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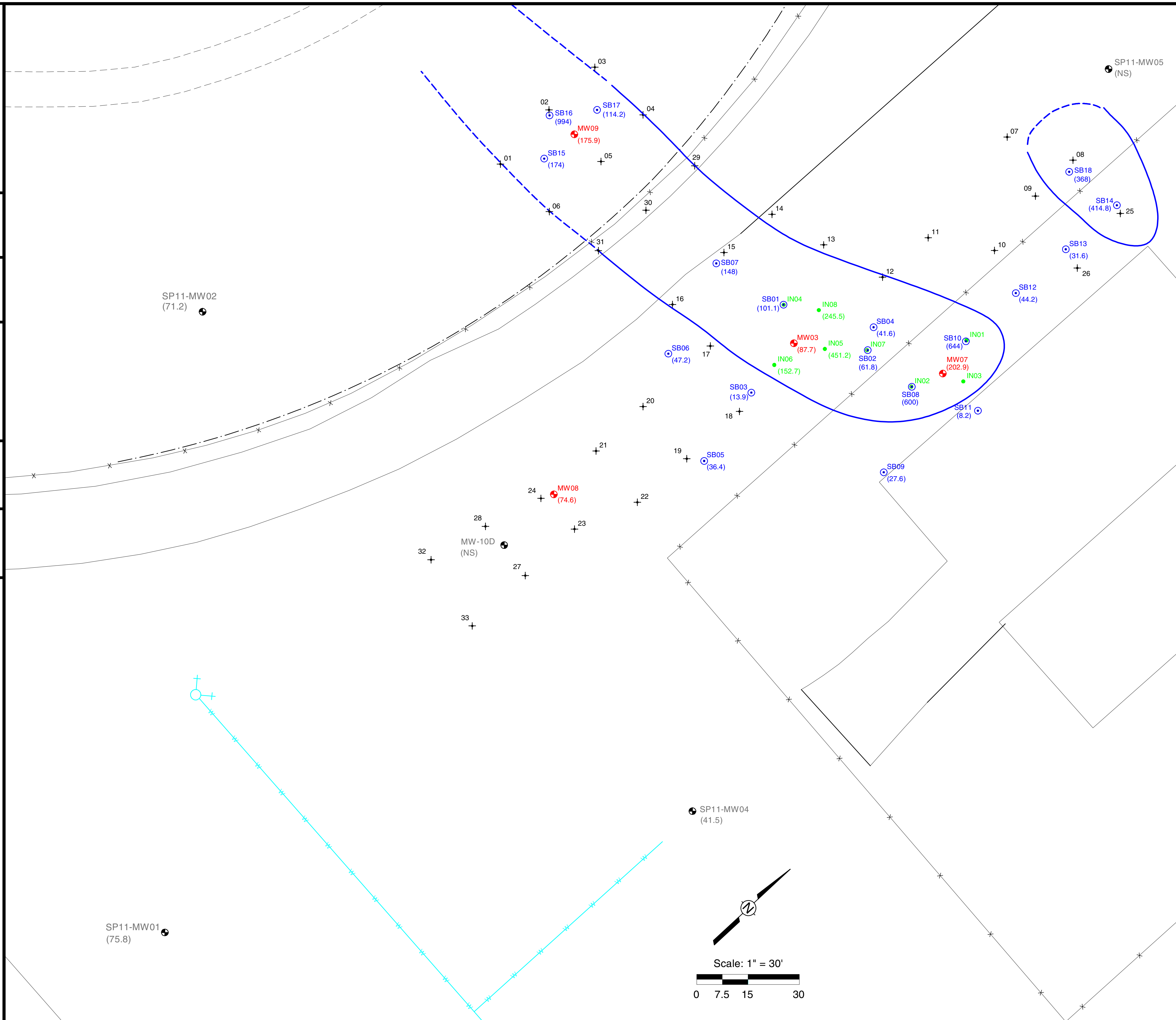

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- (50) TOTAL VOC GROUNDWATER CONCENTRATIONS (µg/L) (UPPER WATER BEARING SAND)
- VOC 100 (µg/L) ISOPLETH (DASHED WHERE INFERRED)
- (NS) NOT SAMPLED
- NOTE: MW-10D HAS BEEN ABANDONED

Figure 2-8.
BASELINE INVESTIGATION
TOTAL VOCs IN THE UPPER
WATERBEARING SAND

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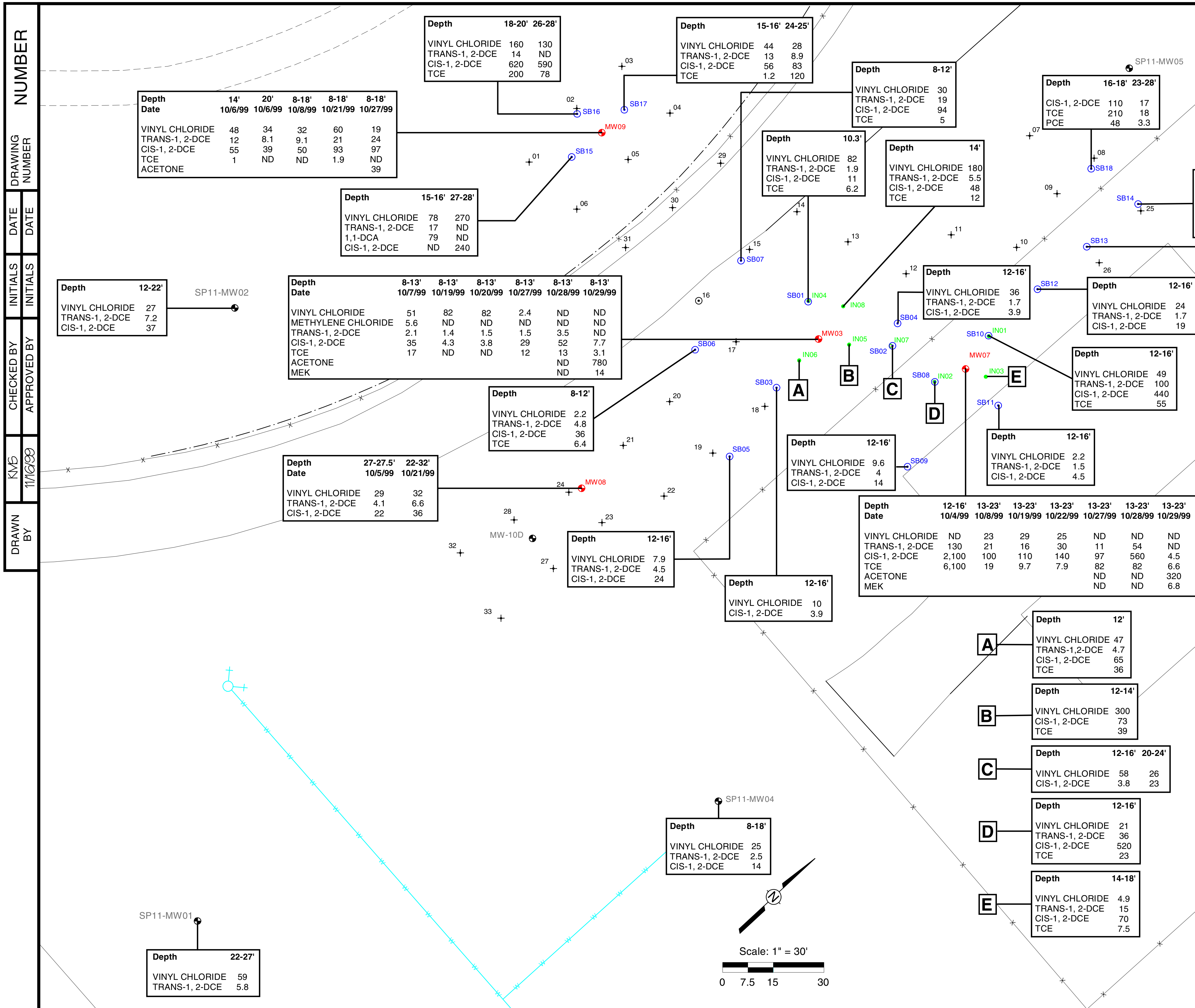
	11/16/99	APPROVED BY	INITIALS	DATE	NUMBER



LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- (ND) NOT DETECTED

NOTE: MW-10D HAS BEEN ABANDONED

Figure 2-9.
BASELINE INVESTIGATION
GROUNDWATER CONTAMINANT
CONCENTRATIONS

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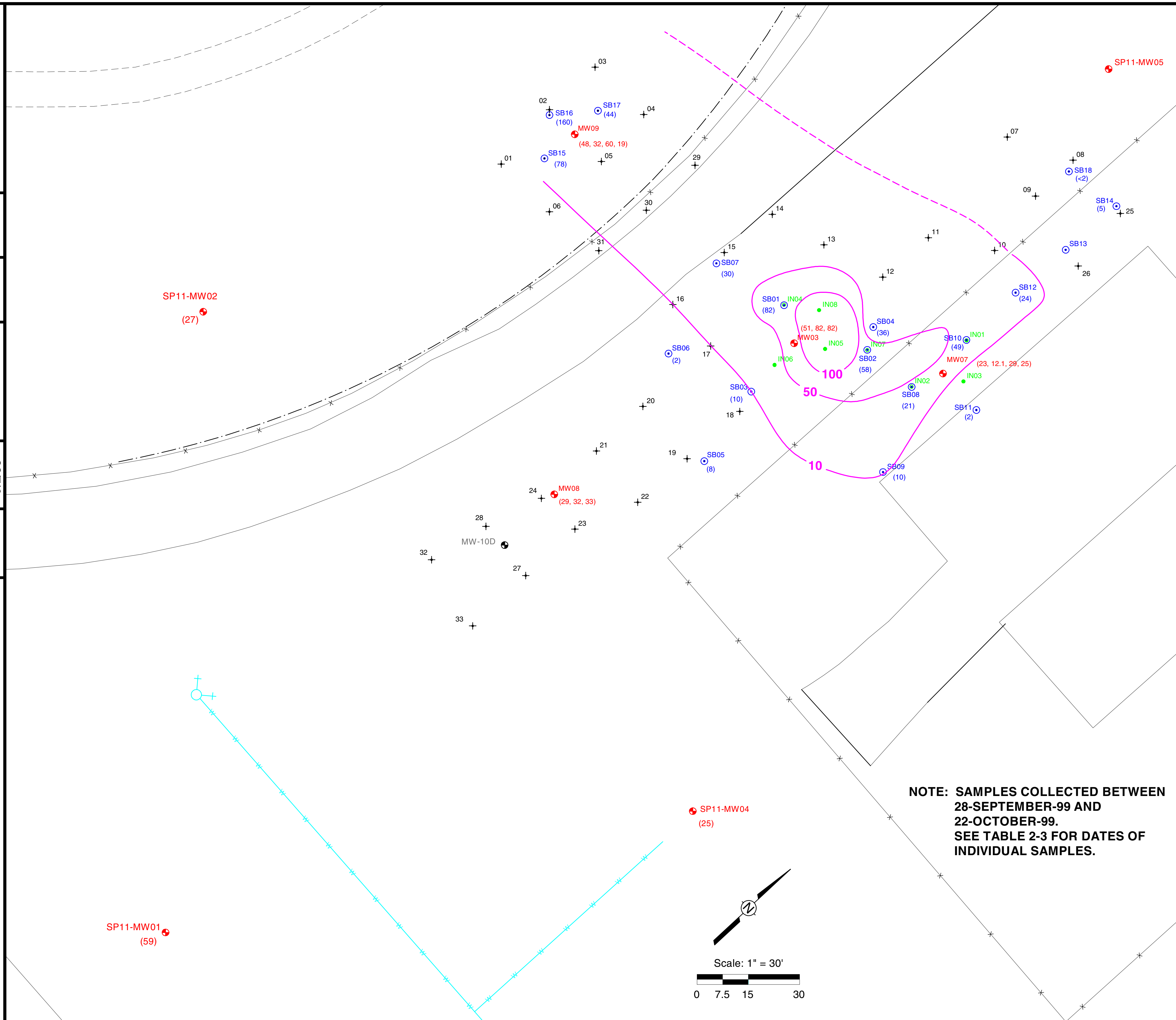

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- NOTE: MW-10D HAS BEEN ABANDONED
- —10— LINE OF EQUAL VINYL CHLORIDE CONCENTRATION (ppb)
- (5) CONCENTRATION OF VINYL CHLORIDE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 2-10.
VINYL CHLORIDE IN GROUNDWATER (UWBZ) PRIOR TO TREATABILITY TESTS.

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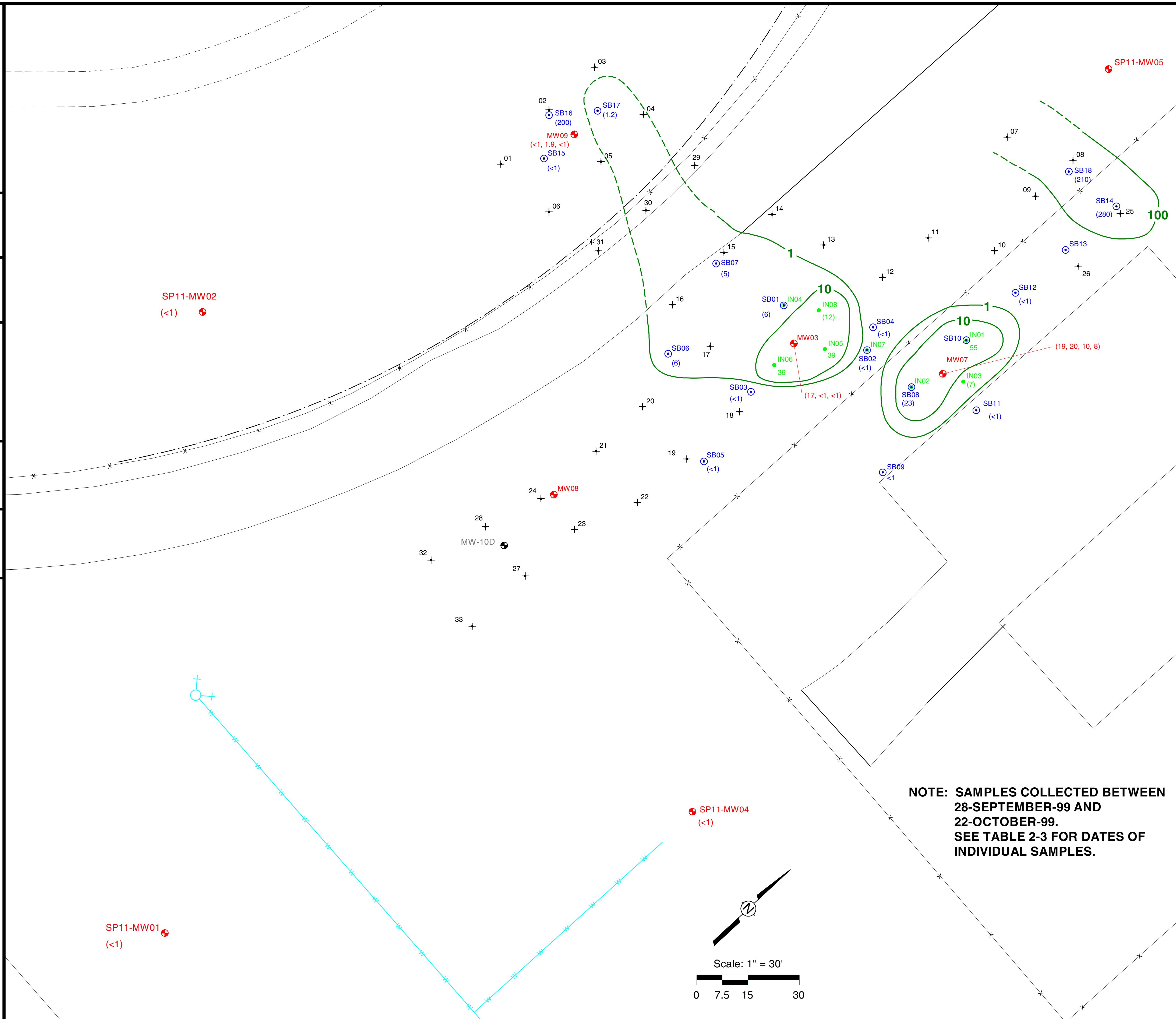

NOTE: SAMPLES COLLECTED BETWEEN 28-SEPTEMBER-99 AND 22-OCTOBER-99. SEE TABLE 2-3 FOR DATES OF INDIVIDUAL SAMPLES.

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- NOTE: MW-10D HAS BEEN ABANDONED
- —10— LINE OF EQUAL TCE CONCENTRATION (ppm)
- (5) CONCENTRATION OF TCE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 2-11.
TCE IN GROUNDWATER (UBWZ)
PRIOR TO TREATABILITY TESTS

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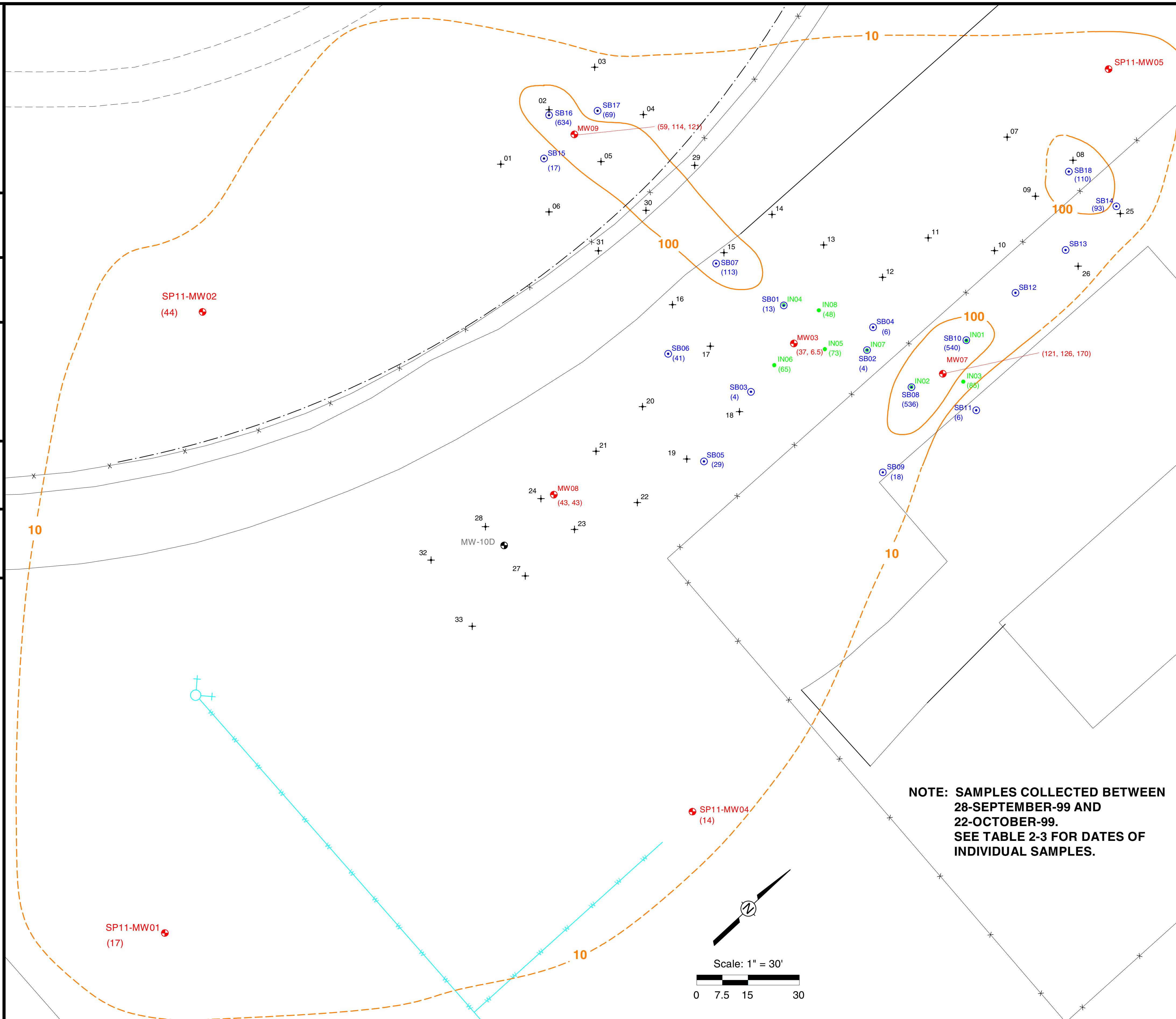
NUMBER



NOTE: SAMPLES COLLECTED BETWEEN 28-SEPTEMBER-99 AND 22-OCTOBER-99. SEE TABLE 2-3 FOR DATES OF INDIVIDUAL SAMPLES.

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- NOTE: MW-10D HAS BEEN ABANDONED
- —10— LINE OF EQUAL DCE CONCENTRATION (ppm)
- **(5)** CONCENTRATION OF DCE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 2-12.
DCE IN GROUNDWATER (UWBZ)
PRIOR TO TREATABILITY TESTS.

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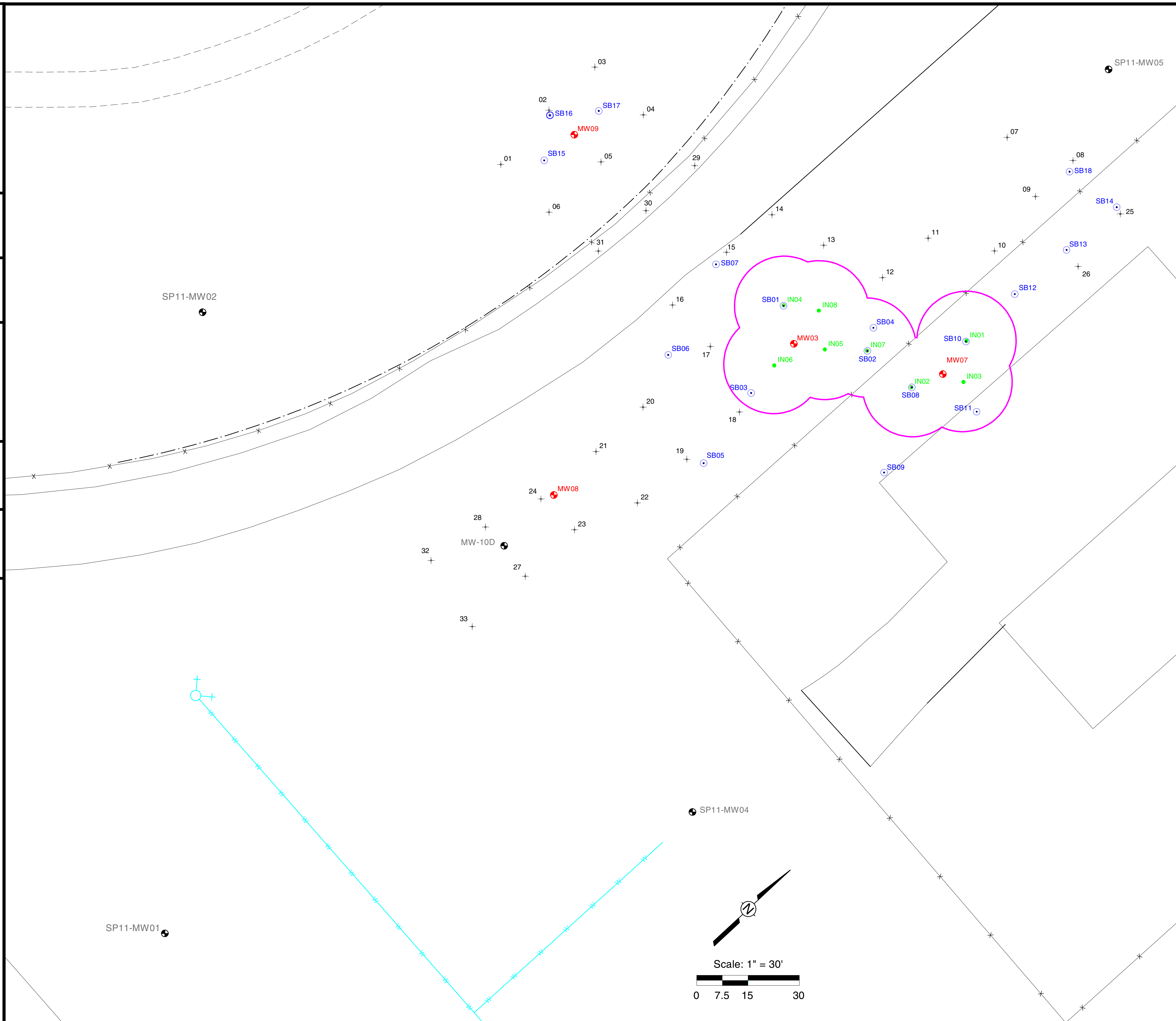

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- APPROXIMATE AREA OF INFLUENCE FENTON'S REAGENT

NOTE: MW-10D HAS BEEN ABANDONED

Figure 3-1.
FENTON'S REAGENT TREATMENT ZONE

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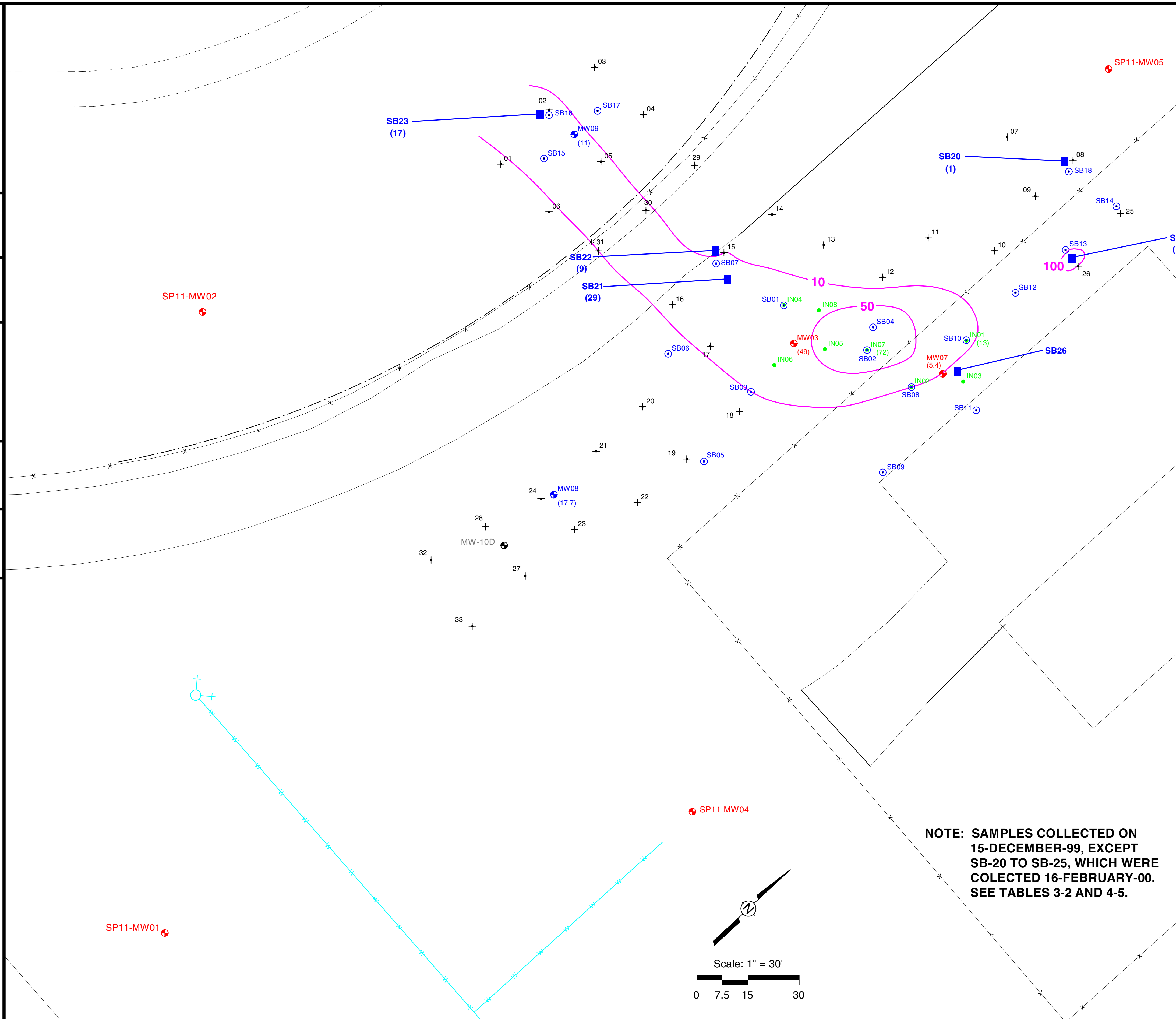
INITIALS	INITIALS
DATE	DATE
DRAWING NUMBER	NUMBER



NOTE: SAMPLES COLLECTED ON 15-DECEMBER-99, EXCEPT SB-20 TO SB-25, WHICH WERE COLECTED 16-FEBRUARY-00. SEE TABLES 3-2 AND 4-5.

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- SAMPLING LOCATIONS
- (ND) NOT DETECTED
- NOTE: MW-10D HAS BEEN ABANDONED
- 10 LINE OF EQUAL VINYL CHLORIDE CONCENTRATION (ppb)
- (5) CONCENTRATION OF VINYL CHLORIDE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 3-2.
VINYL CHLORIDE IN GROUNDWATER (UWBZ) AFTER TREATABILITY TESTS.

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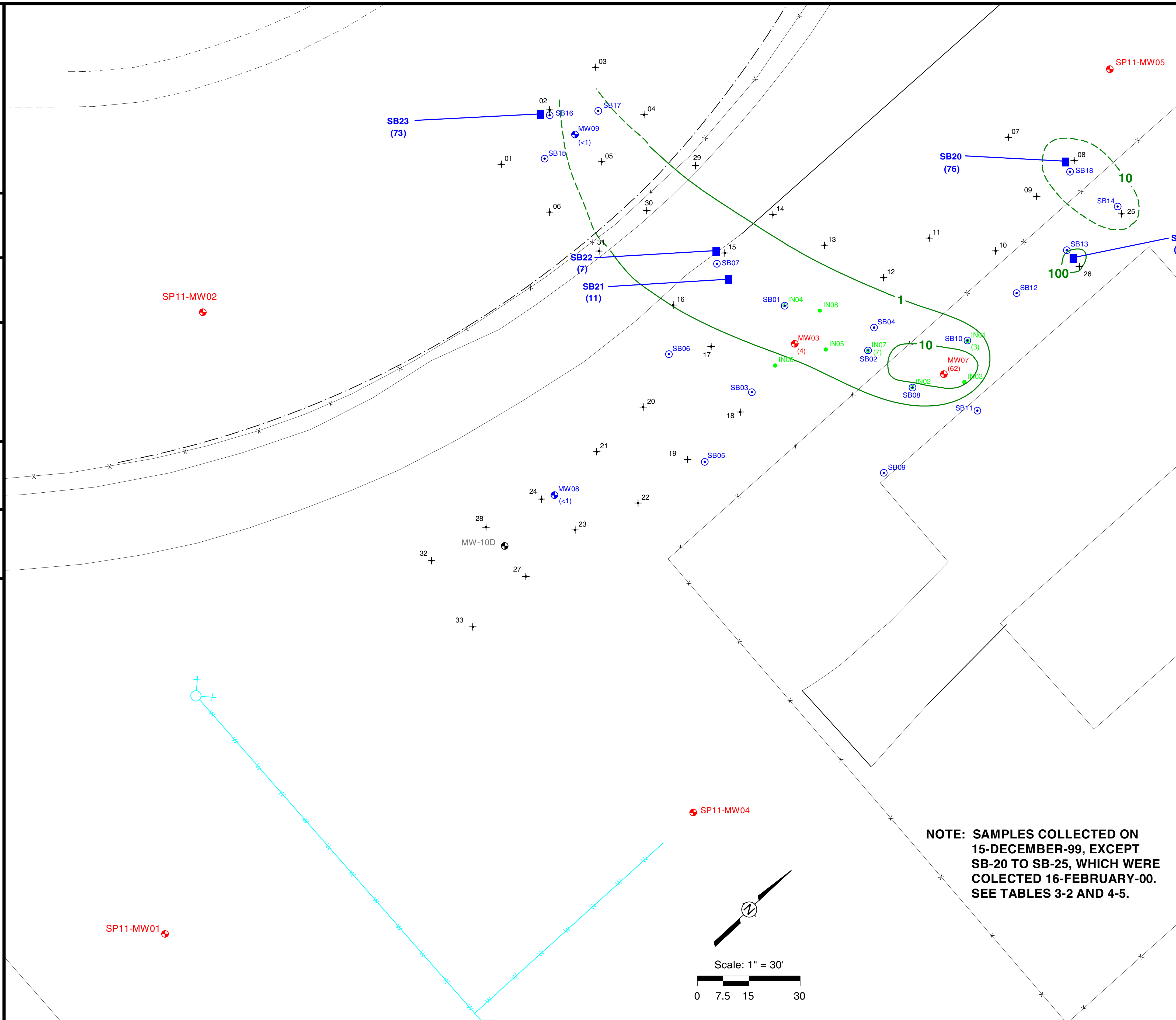
KMS 8/2/00								



NOTE: SAMPLES COLLECTED ON 15-DECEMBER-99, EXCEPT SB-20 TO SB-25, WHICH WERE COLECTED 16-FEBRUARY-00. SEE TABLES 3-2 AND 4-5.

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- SAMPLING LOCATIONS
- NOTE: MW-10D HAS BEEN ABANDONED
- —10— LINE OF EQUAL TCE CONCENTRATION (ppb)
- **(5)** CONCENTRATION OF TCE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 3-3.
TCE IN GROUNDWATER (UWBZ)
AFTER TREATABILITY TESTS.

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IT CORPORATION

DRAWING NUMBER | NUMBER
DATE | DATE
INITIALS | INITIALS
CHECKED BY | APPROVED BY
KMG | 8/2/00
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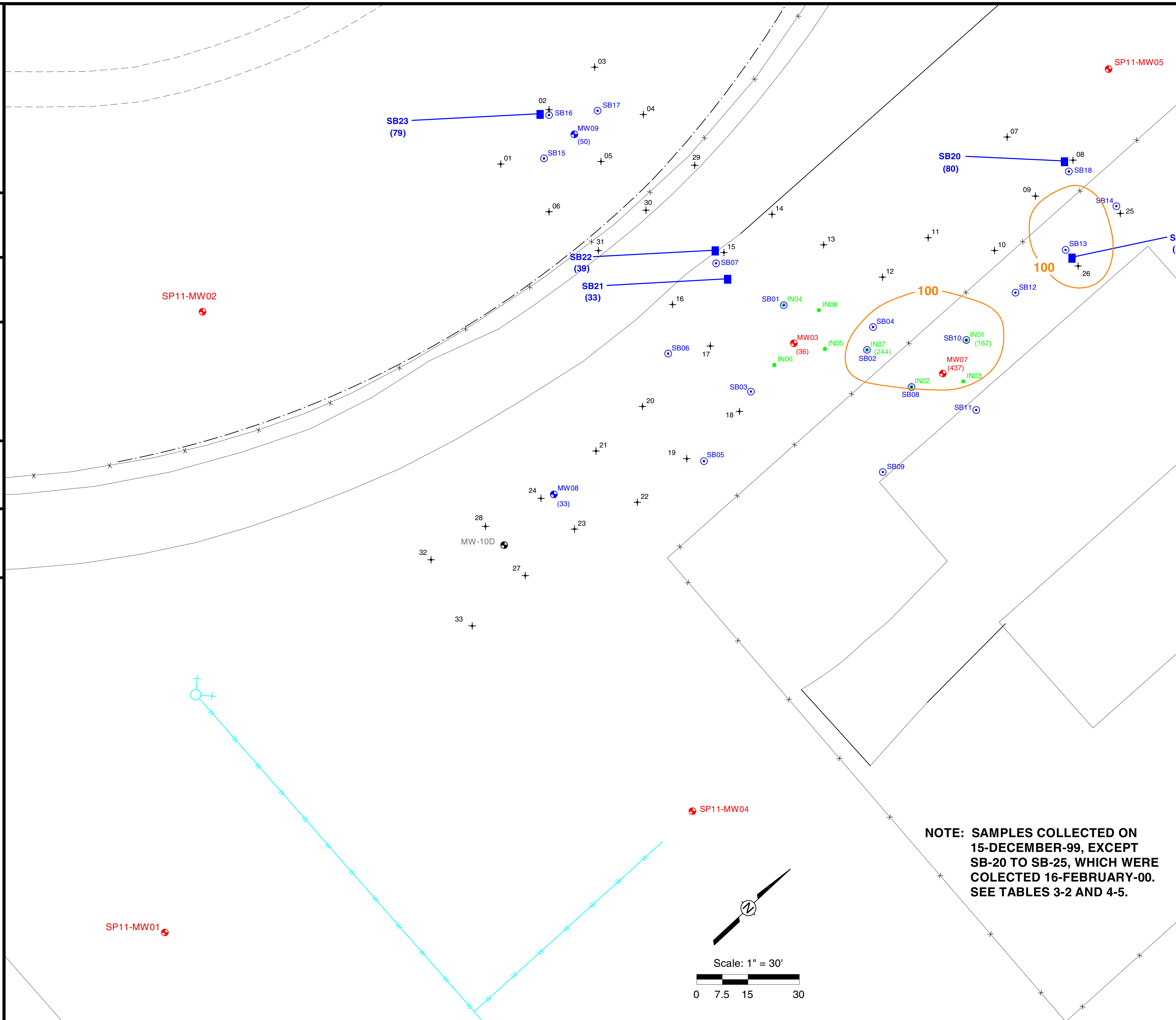

LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- SAMPLING LOCATIONS
- NOTE: MW-10D HAS BEEN ABANDONED
- — 10 — LINE OF EQUAL DCE CONCENTRATION (ppb)
- (5) CONCENTRATION OF DCE (ppb)
- UWBZ UPPER WATER BEARING ZONE

Figure 3-4.
DCE IN GROUNDWATER (UWBZ)
AFTER TREATABILITY TESTS.

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FIGURE 3-5

MW-3 Vinyl Chloride

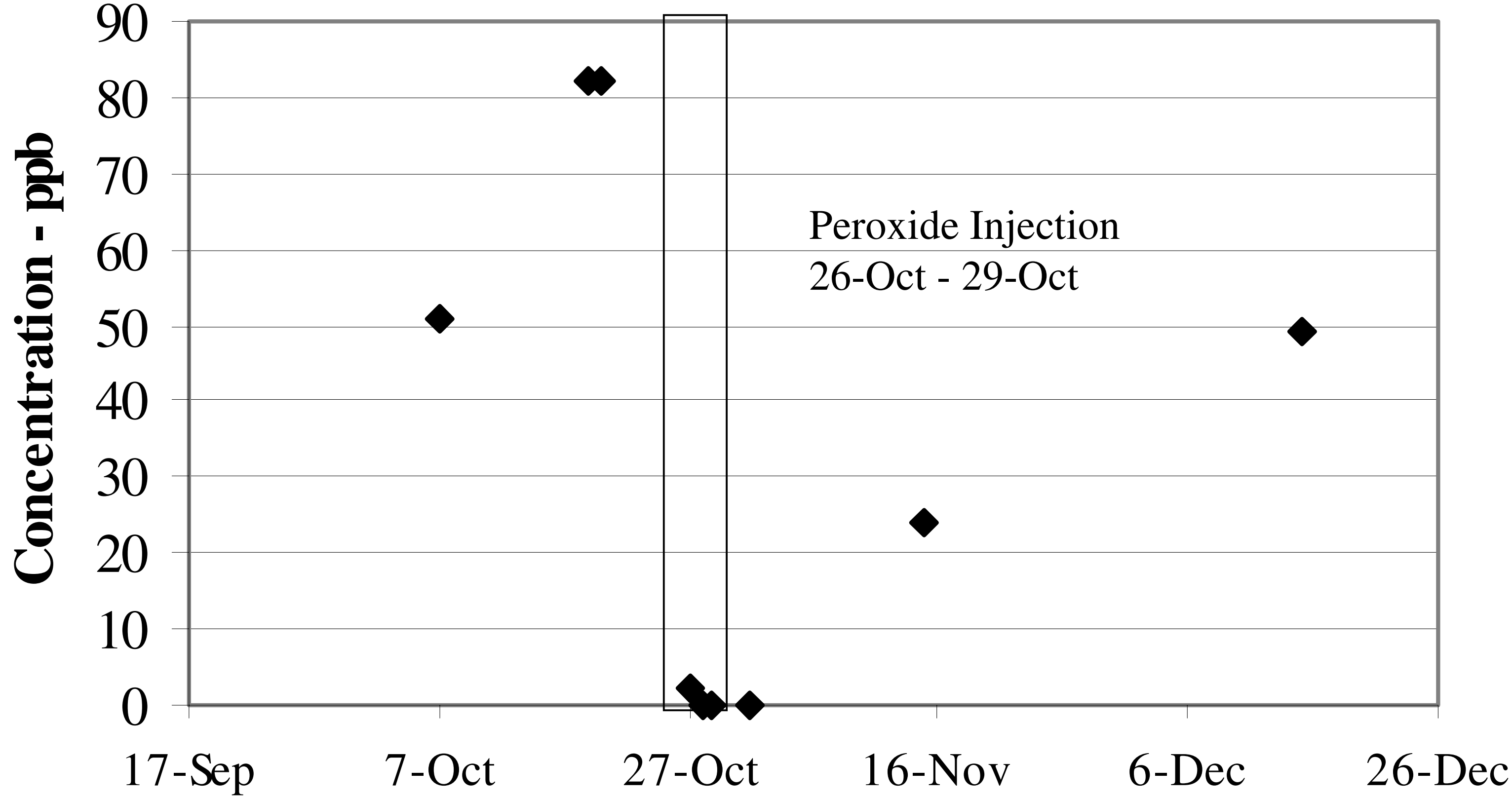
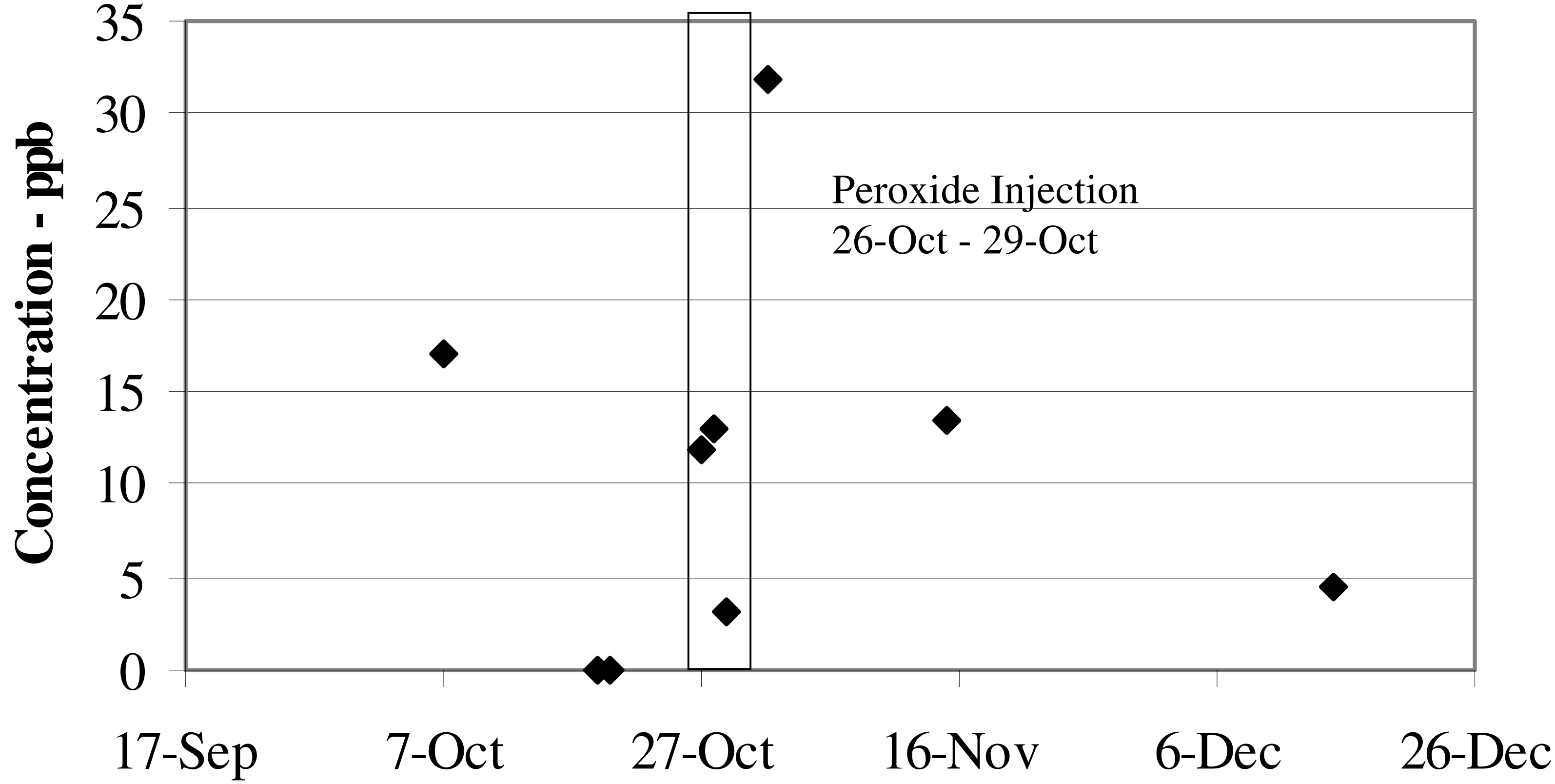


FIGURE 3-6

MW-3 TCE



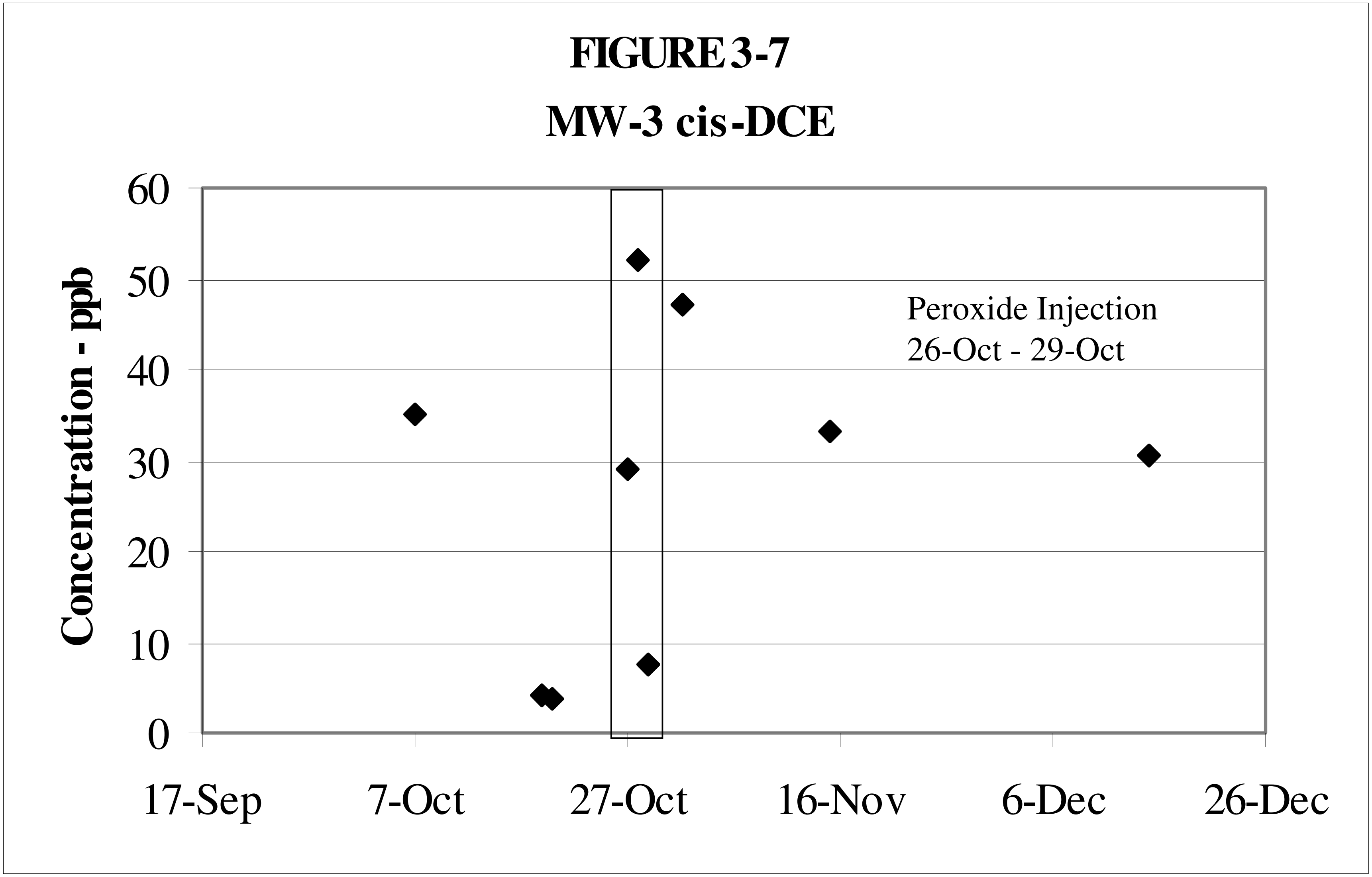


FIGURE 3-7
MW-3 cis-DCE
Concentration - ppb
60
50
40
30
20
10
0
17-Sep
7-Oct
27-Oct
16-Nov
6-Dec
26-Dec
Peroxide Injection
26-Oct - 29-Oct

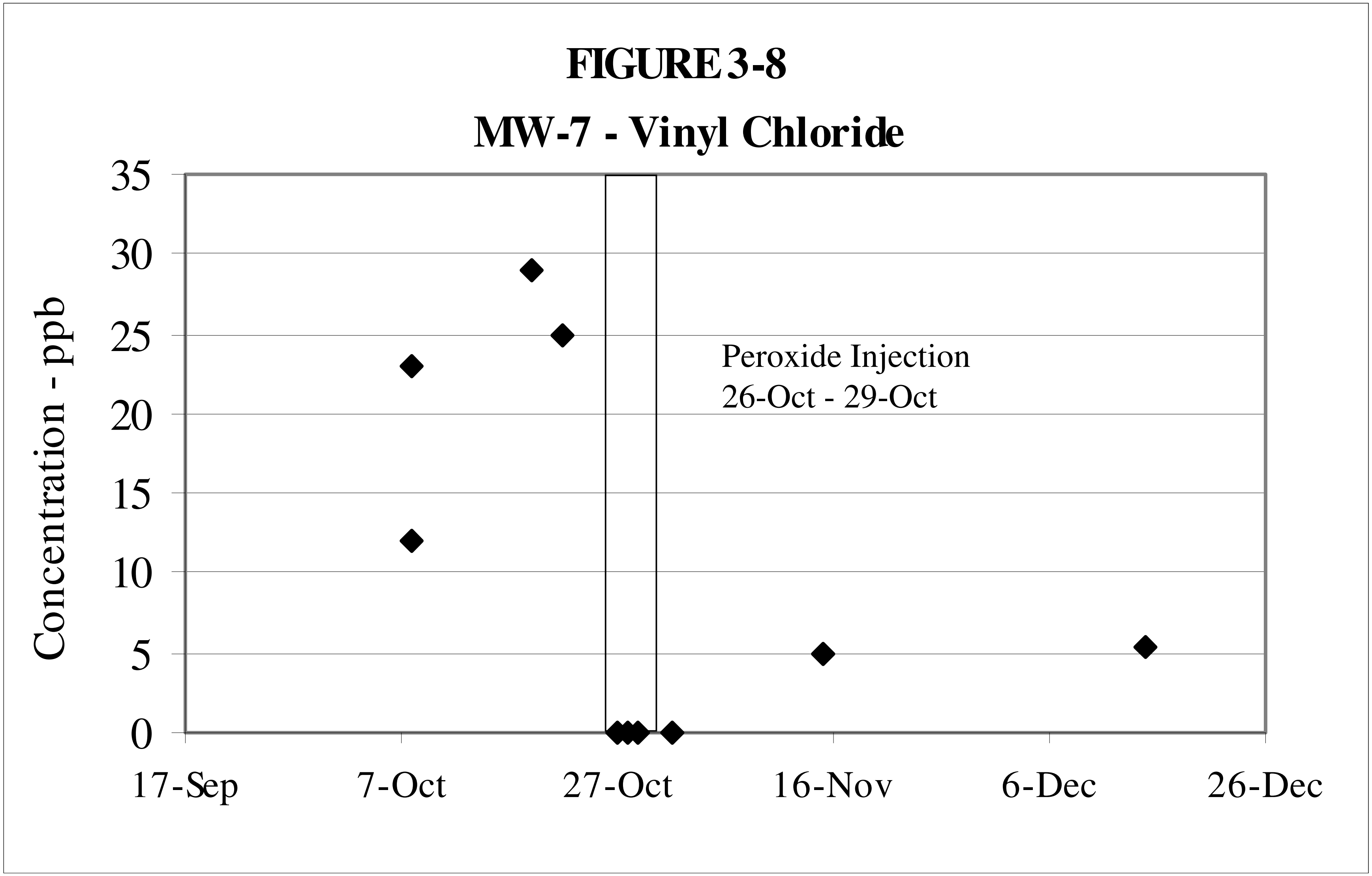


FIGURE 3-8
MW-7 - Vinyl Chloride
Concentration - ppb
35
30
25
20
15
10
5
0
17-Sep
7-Oct
27-Oct
16-Nov
6-Dec
26-Dec
Peroxide Injection
26-Oct - 29-Oct

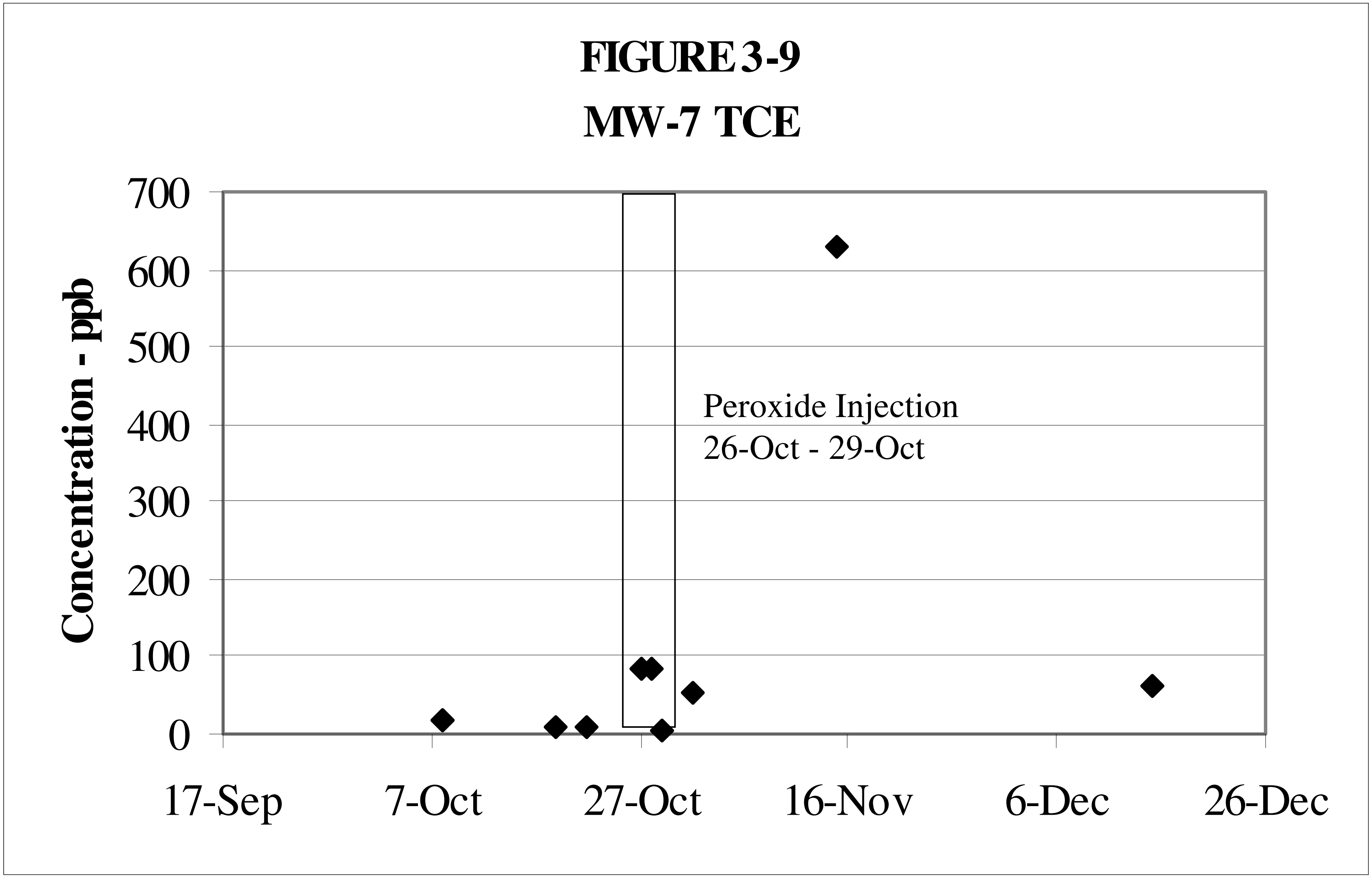
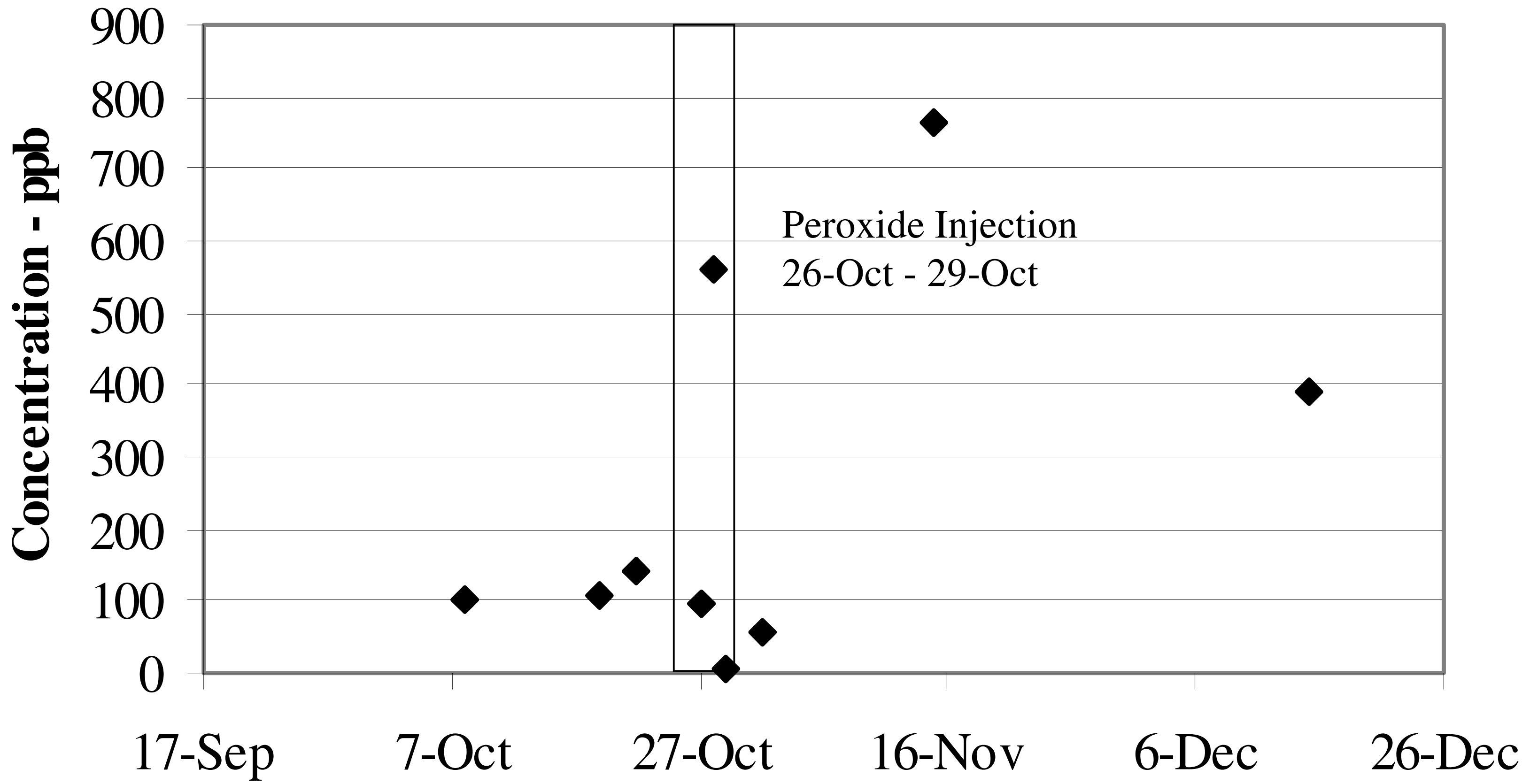


FIGURE 3-9
MW-7 TCE
Concentration - ppb
700
600
500
400
300
200
100
0
Peroxide Injection
26-Oct - 29-Oct
17-Sep
7-Oct
27-Oct
16-Nov
6-Dec
26-Dec

FIGURE 3-10

MW-7 cis-DCE



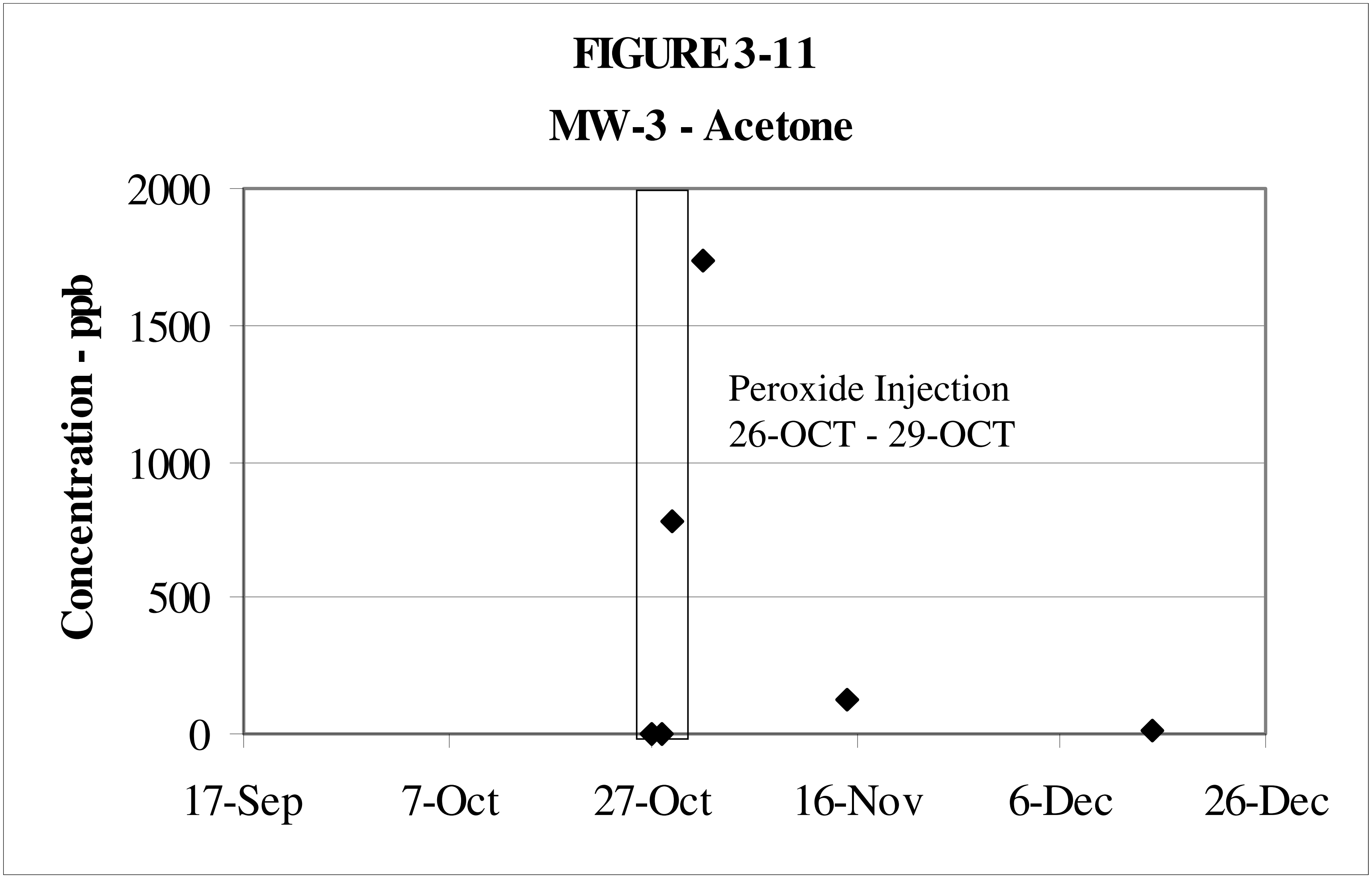


FIGURE 3-11
MW-3 - Acetone
Concentration - ppb
2000
1500
1000
500
0
Peroxide Injection
26-OCT - 29-OCT
17-Sep
7-Oct
27-Oct
16-Nov
6-Dec
26-Dec

FIGURE 3-12
MW-7 Acetone

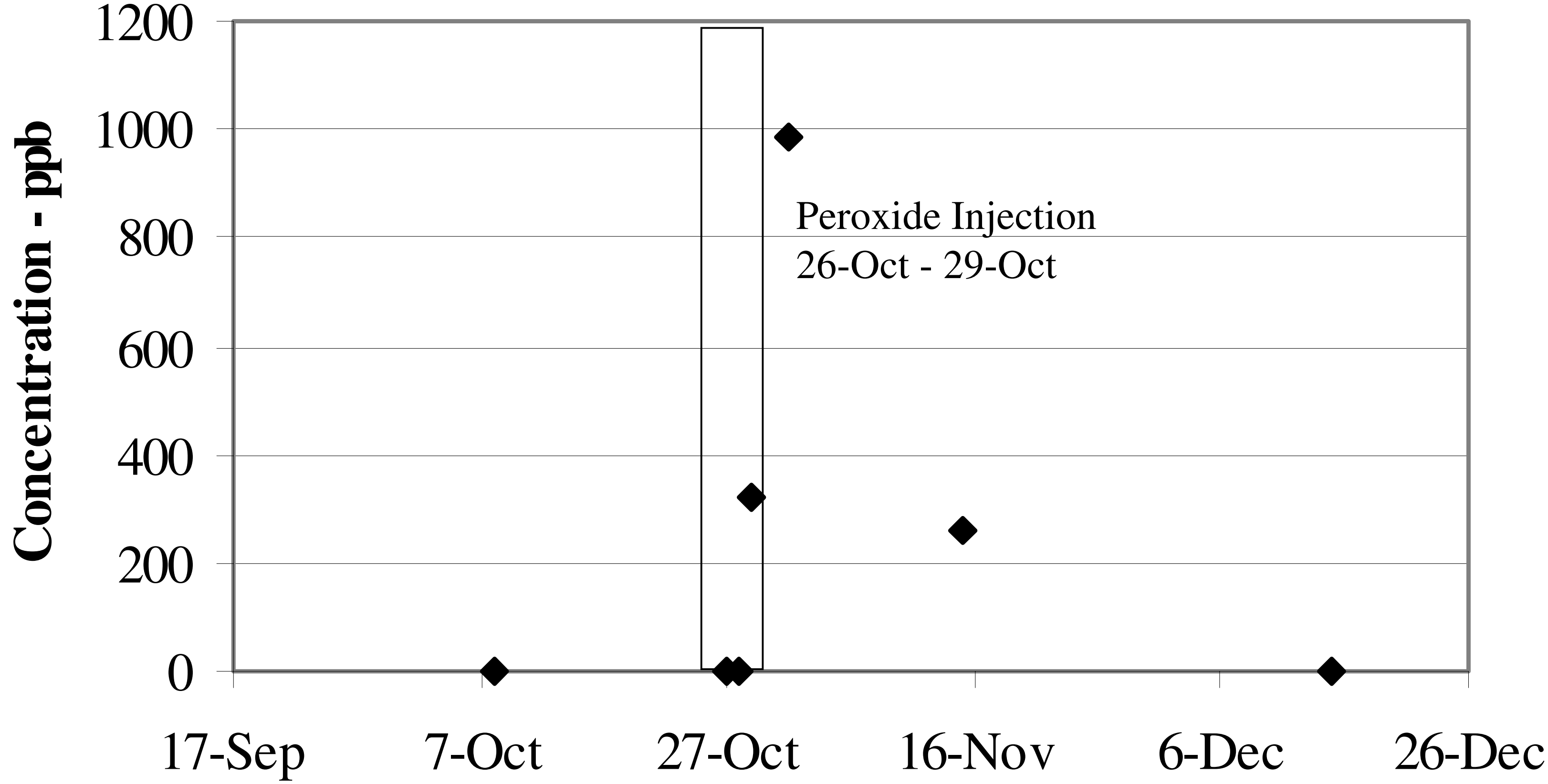
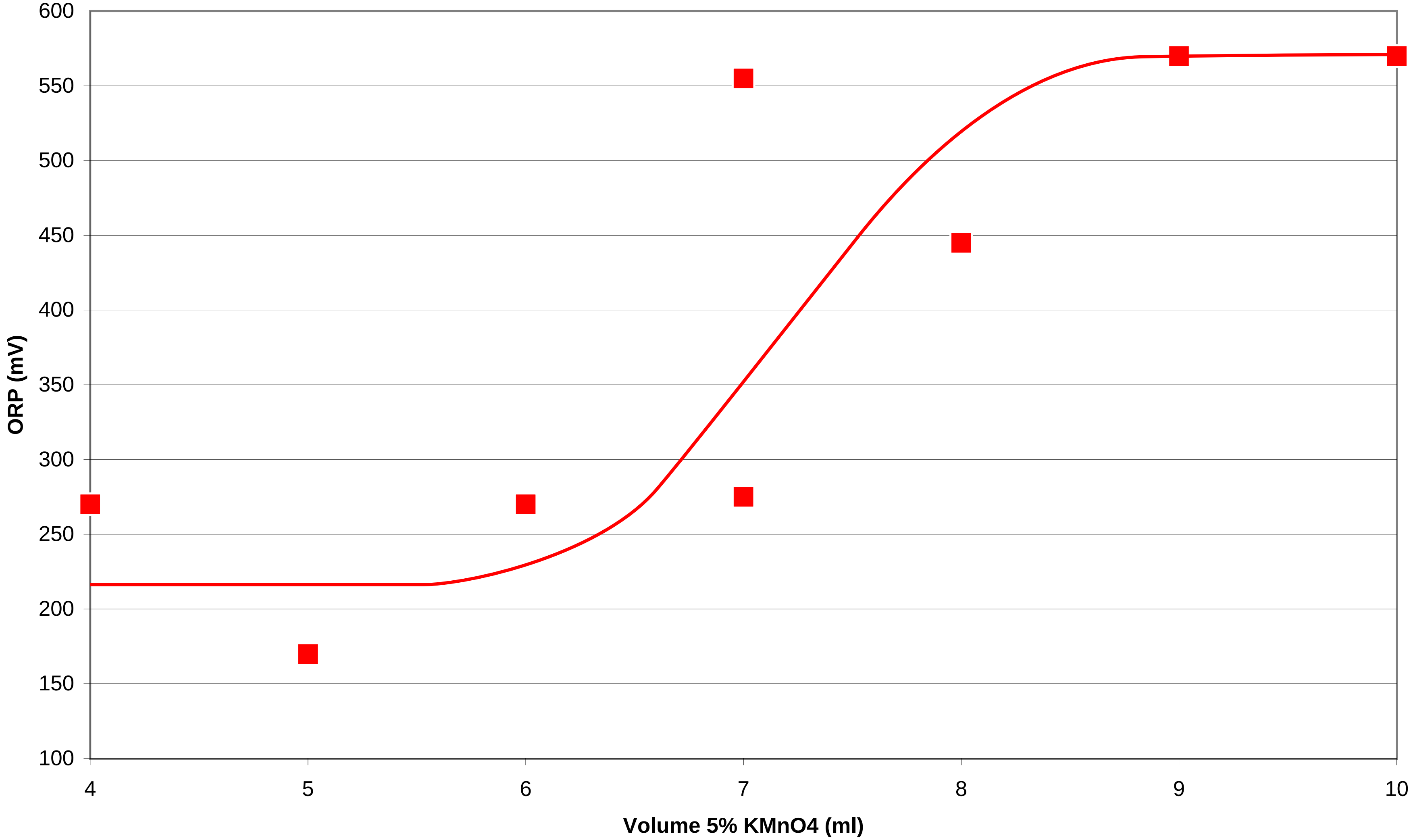
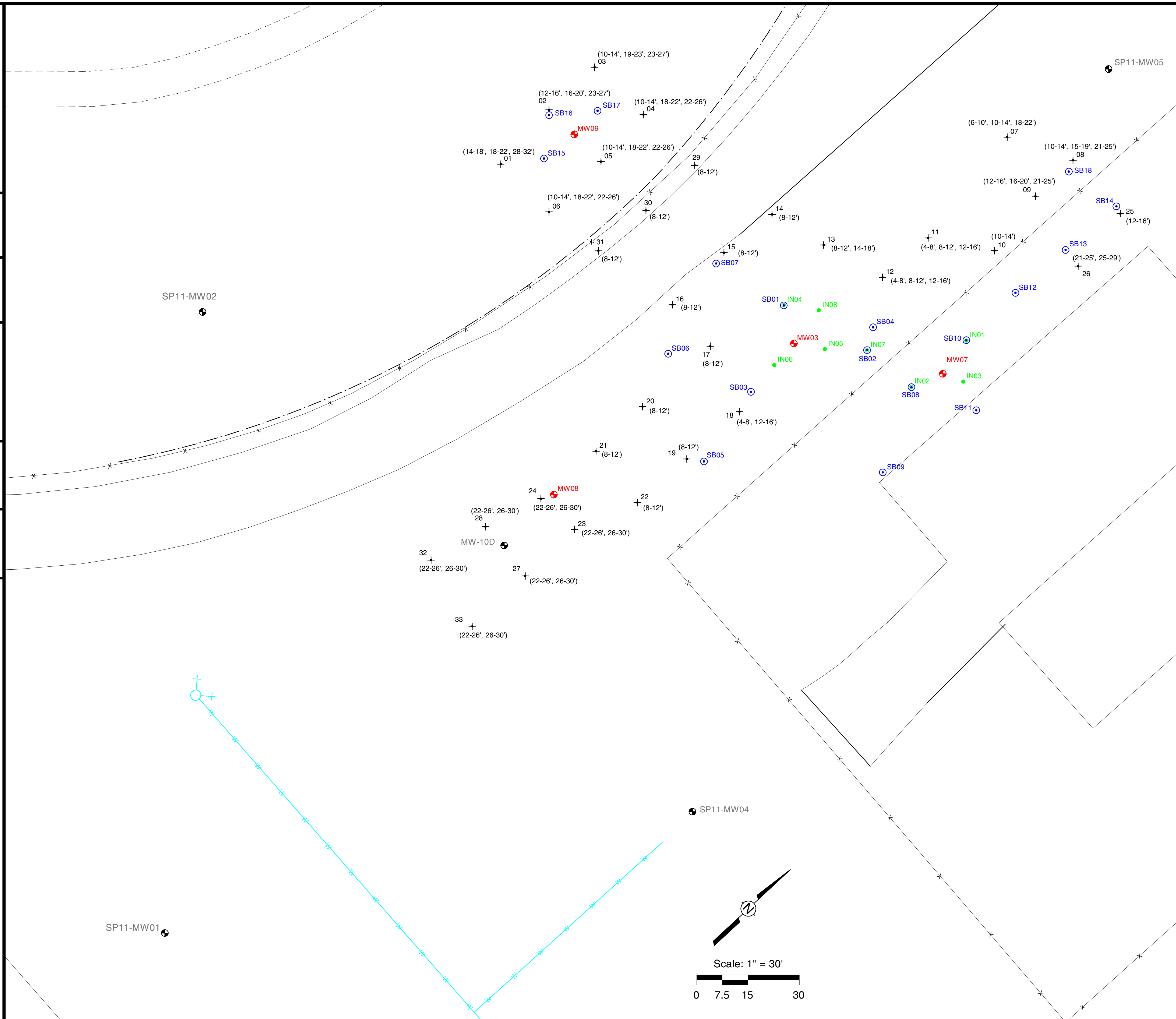


Figure 4-1

Oxidation-Reduction Potential vs. Potassium Permanganate Addition





LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- EXISTING MONITORING WELL
- (8-12') INJECTION INTERVALS (FEET BELOW GROUND SURFACE)

NOTE:
MW-10D HAS BEEN ABANDONED

Figure 4-2.
PERMANGANATE INJECTION INTERVALS

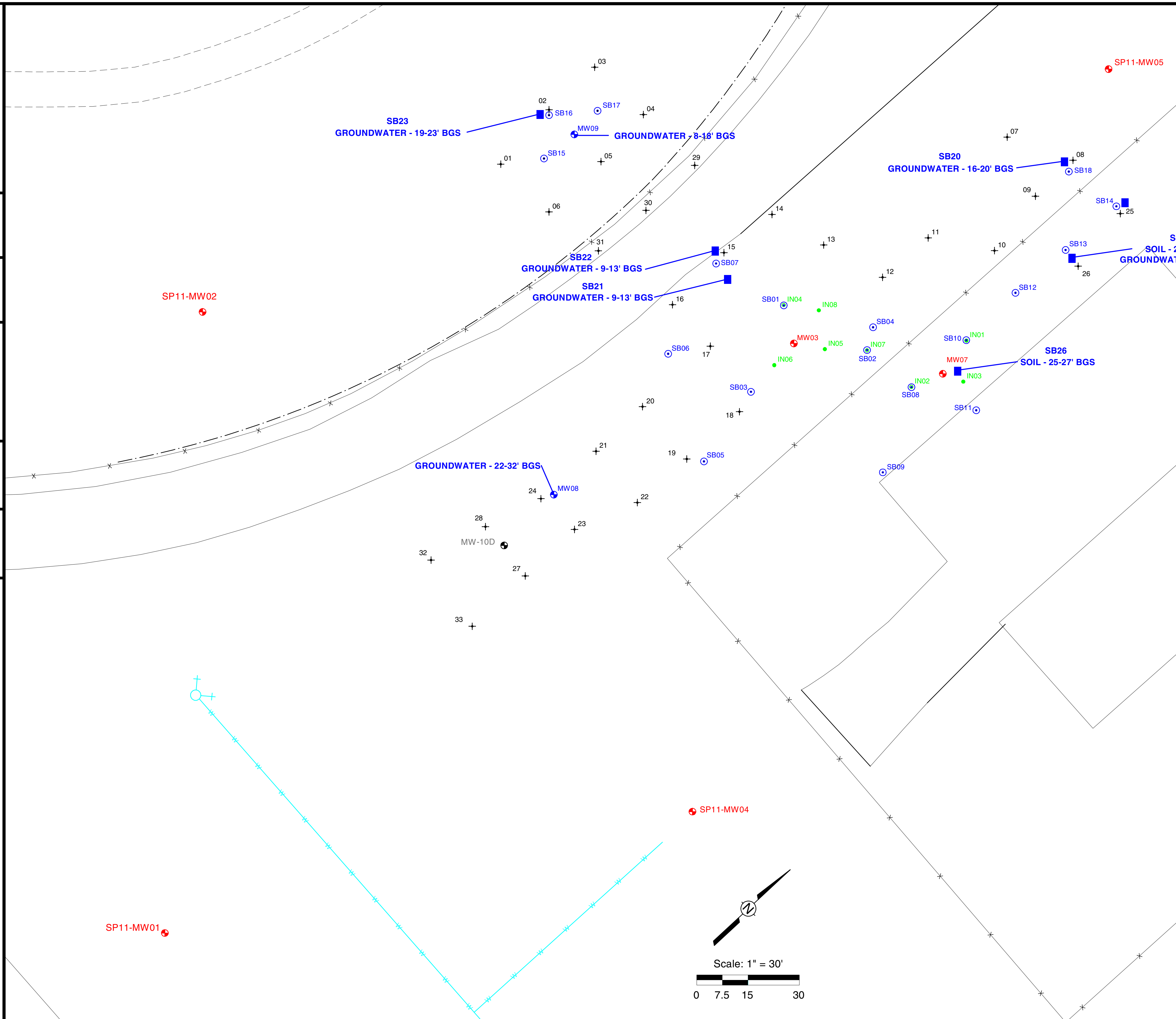
PREPARED FOR

WRIGHT-PATTERSON AIR FORCE BASE

IT CORPORATION
11499 CHESTER ROAD
CINCINNATI, OHIO 45246

IT CORPORATION

NUMBER | DRAWING NUMBER | DATE 11/16/99 | DATE | INITIALS KMS | INITIALS | CHECKED BY | APPROVED BY | DRAWN BY



LEGEND:

- MONITORING WELL LOCATION
- FENTON'S REAGENT/PEROXIDE INJECTION WELL LOCATION
- GEOPROBE LOCATION
- PERMANGANATE INJECTION POINT
- APPROXIMATE LOCATION OF WATER LINE
- HYDRANT
- SAMPLING LOCATIONS
- IN01 NOT DETECTED

NOTE: MW-10D HAS BEEN ABANDONED

Figure 4-3.
PERMANGANATE PERFORMANCE
SAMPLING LOCATIONS.

PREPARED FOR

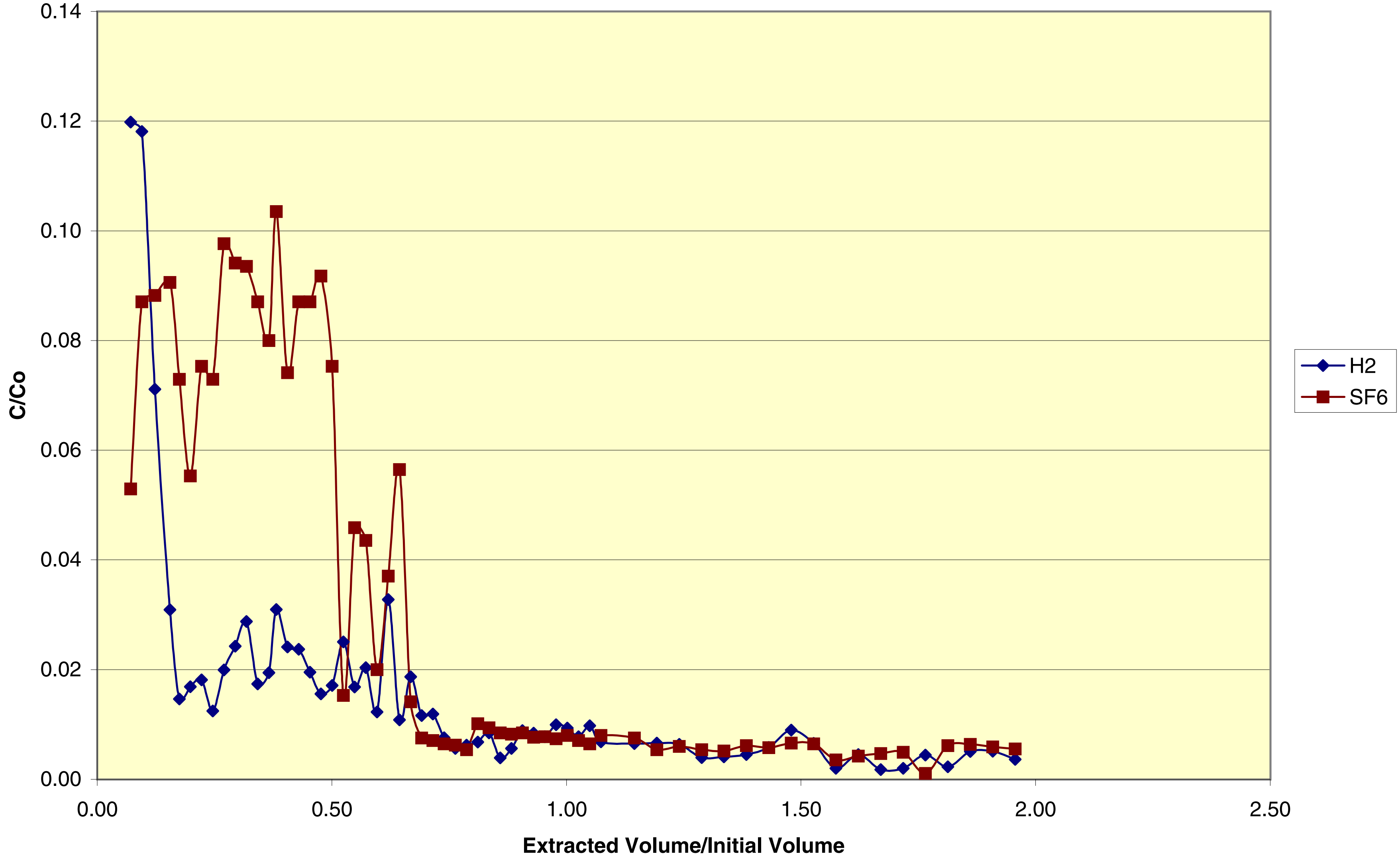
WRIGHT-PATTERSON AIR FORCE BASE

IT CORPORATION

IT CORPORATION
11499 CHESTER ROAD
CINCINNATI, OHIO 45246

NUMBER | DRAWING NUMBER | DATE 11/16/99 | DATE | INITIALS | INITIALS | CHECKED BY | APPROVED BY | DRAWN BY KMS

FIGURE 5-1
Hydrogen and Sulfur Hexafluoride Recovery



APPENDIX A

WORK PLAN VARIATIONS

Appendix A

Work Plan Variations

The procedures for the baseline characterization and the treatability studies are presented in the document entitled *Final Work Plan, Treatability Studies at Further Action Area A and Further Action Area B (IT, 1999).* Because of changes in field conditions or a different understanding of the methods used during the treatability study several changes, or variations, were introduced. The variations are documented below, listing the task, procedure variation, and the rational for the change.

1. Change in the number of exploratory borings – The approved Work Plan outlined that 10 soil borings would be advanced over a two day period. A total of 19 borings were advanced, with soil and groundwater samples collected from each of the locations. The original locations shown on figure 3-1 of the work plan were the initial 10 sampling locations. The investigation was expanded to assist in delineation of the extent of the contamination present.
2. Depth of borings – The approved Work Plan stated that the borings were to be advanced to bedrock, or sample probe refusal. ~~Once field work was initiated it was concluded that the borings were to be completed in the silty-clay found below the second sand layer (20-25' bgs). Previous investigations at FAA-B showed groundwater could be expected to be present in two sand layers present in the subsurface at FAA-B and not present below the lower sand layer. The previous investigations also showed higher concentrations of contamination to be present in the upper sand layer. Therefore advancing the boring below the lower sand seam was determined to be unnecessary based on the goals of the investigation, which was to delineate the source area of the contamination.~~

   The goal of the baseline characterization was to identify the location of the vinyl chloride source area. Previous investigation in the area showed that the contamination is primarily in the upper water bearing zone in FAA-B and that the second sand stringer, when present, is at a depth of approximately 20 feet below ground surface. Therefore if the sand was not encountered at 20 – 25' the boring was terminated.

Contamination has been detected in the lower sand stringer, but at a much lower concentration. Therefore the investigation targeted sampling and analysis of the upper water bearing zone. This allowed collection of samples from a wider area to better define the extent of contamination in the upper water bearing zone. Minimizing the number of borings advanced through to the second sand stringer also decreased the opportunity for cross contamination of the water bearing zones.

Several borings were advanced to bedrock. SB13, SB18, and SB19 were advanced to bedrock. SB13 was advanced deeper until water was observed at 28 feet below ground surface. Two water bearing sands were detected at SB18 and bedrock was encountered at 24 feet at SB19. SB15, SB16, and SB17 were also advanced to bedrock to better define the geologic profile in the area adjacent to the firing range, which was not previously characterized.

~~3.~~

3. Number of Samples collected during the baseline investigation – The work plan had a total of 34 soil and 23 groundwater samples to be collected during the baseline investigation. Actual sample numbers were 57 soil and 47 groundwater. The following table provides a summary of the samples and the reason for variance formt the work plan.

Task	**Work Plan Number of Samples**		**Actual Number of Samples**		**Reason For Variance**
	Soil	Groundwater	Soil	Groundwater	
Baseline	20	7	44	26	Expanded scope to delineate extent of contamination
Monitor Wells	6	8	6	17	Temporal data
Injection Wells	8	8	7	4	Several injection wells were installed as overdrills of soil borings
Total	34	23	57	47	

In addition to the samples outlined above, four duplicate soil samples and two duplicate groundwater samples were submitted to a contract laboratory for analysis as a quality control check on the mobile laboratory.

4. Monitor well locations – The Work Plan showed three monitor wells, closely spaced in the vicinity of MW-3. This was proposed to provide monitoring points within the zone treated by Fenton's Reagent. The results of the baseline investigation indicated a different distribution of contamination than estimated during the development of the work plan. Therefore new well locations were selected. MW-7 was placed in the zone where the highest concentration of VOCs was detected, MW-8 was placed in an are believed to be outside the man contamination zone and MW-9 was installed to monitor groundwater conditions just upgradient of the gun range. MW-3 and MW-7 provided monitoring points for performance monitoring of the Fenton's Reagent.

5. Soil sampling intervals – the Work Plan called for the sampling interval to be 5-foot intervals. The sampling tool used on the Geoprobe rig was a 4-foot interval. Samples were collected continuously, consistent with the Work Plan.

6. Groundwater monitoring during Fenton's injection – The sampling frequency during injection activity was decreased significantly. This was done for several reasons, which are listed below:
   - Sample collection by micropurging was time consuming, allowing the collection of only one sample per day from a maximum of 6 wells.
   - The mobile lab, at the time of the Fenton's injection, was at maximum capacity out due to analysis of the sulfur hexafluoride analyses.
   - Analysis of samples collected from the injection wells would not yield useful data due to the use of these wells for the injection of Fenton's Reagent.

APPENDIX B

BORING AND WELL COMPLETION LOGS

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB01/IN04
TOTAL DEPTH: 20'
FILE NAME RWP-SB01

PROJECT INFORMATION

PROJECT:
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 09-28-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: Well was backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		0.0 ppm bkg Soil Sample WP-FAAB-SB01-SS01 0'-0.5'
	3 ppm @ 1'				SILT: gray (10yr 6/1) silt, moist, soft, trace poorly graded gravel		
-2		ML	60 (2' to 4' interval)		CLAY: yellowish brown (10yr 5/4), trace silt and sand, moist, stiff		
					GRAVEL: 1" seam large gravel at 3'5"		
-4	2 ppm @ 4'	CL			SILTY CLAY: gray (10yr 6/1) moist, soft, with poorly graded gravel		Soil Sample WP-FAAB-SB01-SS01 4'-8'
-6		OL	60 (4' to 8' interval)				
					CLAY: trace silt, moist, stiff		
-8	2.6 ppm @ 8'	OL			SILTY CLAY: gray (10yr 6/1) moist, soft with poorly sorted gravel		Water Sample WP-FAAB-SB01-GW01 8'-12'
-10			50 (8' to 12" interval)				
		GP			GRAVEL AND SAND: wet, loose		
-12	3.6 ppm @ 12'	CL			SANDY CLAY: black (10yr 2/1) moist, soft		
					GRAVEL: gray (10yr 5/1) clay and large gravel, 0.5 - 3 cm		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
14		CL	50 (12' to 16' interval)		CLAY: grayish brown (10yr 5/2), trace silt, medium stiff to very stiff, moist		
-16	1.6 ppm @ 16'						
		CL					
-18			70 (16' to 20' interval)				
	3.2 ppm @ 19.5'						
-20							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB02
TOTAL DEPTH: 24'
FILE NAME: RWP-SB02

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 9-28-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: Tim Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD: 4-foot direct push method

NOTES: Well was backfilled with bentonit chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0	7.1 ppm @ .1'				Topsoil		0.0 ppm bkg
					SAND AND SILT: brown (10yr 5/3), moist, loose		Soil Sample WP-FAAB-SB02-SS02 from 0.0'-0.5'
-2		SM	80 (0.5' to 4')				
					CLAY: very dark gray (10yr 3/1), trace silt, stiff, moist		
-4	3.2 ppm @ 4'	CL			CLAY: dark yellowish brown (10yr 4/6), with sand and gravel, trace silt, medium stiff to stiff, moist		Soil Sample WP-FAAB-SB02-SS01 from 4'-8'
			80 (4' to 8')		CLAY: black (10yr 2/1), trace silt, stiff, moist		
-6							
-8	7.8 ppm @ 8'				CLAY: gray (10yr 6/1), glacial fill material, sand and gravel moist, medium stiff		
-10		SP	80 (8' to 12')				
-12							
	5.1 ppm @ 12.5'						Water Sample WP-FAAB-SB02-GW01

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14			40 (12' to 16')				
					GRAVELLY SAND: wet loose, poorly sorted		
-16	4.6 ppm @ 16'				CLAY: black (10yr 2/1), trace silt, stiff, moist, trace poorly sorted pebbles		
		CL	60 (16' to 20')				
-18							
-20	5.6 ppm @ 20'						Water Sample WP-FAAB-SB02-GW02
-22	5.2 ppm @ 23.5'		100 (20' to 24')				
-24							

IT CORPORATION	**FIELD BOREHOLE LOG**
	BOREHOLE NO: VW02/SB03
	TOTAL DEPTH: 20'
	FILE NAME: RWP-VW02-SB03

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	FAA-B	DRILLING CO:	AST
SITE LOCATION:	WPAFB, OH	DRILLER:	Tim Setty
JOB NUMBER:	781791	RIG TYPE:	5400 Model
LOGGED BY:	V. Voisard	METHOD OF DRILLING:	Geoprobe
PROJECT MANAGER:	R. Sinha	SAMPLING METHOD	4-foot direct push method
DATE DRILLED:	9-28-99		

NOTES: SB03 was converted to VW02 on 10-13-99, using H.S.A. methods

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
2							
0					Topsoil		
	3.8 ppm @ 0.5'				CLAY AND SILT: yellowish brown (10yr 5/6), poorly sorted gravel, moist, medium stiff		Soil sample WP-FAAB-SB03-SS02 0.0'-0.5'
-2		ML	90 (0' to 4')				
-4	2.8 ppm @ 4'				CLAY: very dark brown (10yr 2/2), trace silt, some poorly sorted gravel, stiff, moist		Soil Sample WP-FAAB-SB03-SS01 4'-8'
		CL					
-6			100 (4' to 8')		CLAY: gray (10yr 5/1), trace silt, poorly sorted gravel, some Fe staining, very stiff, moist		Riser and screen - schedule 40 PVC
-8	5.4 ppm @ 8'				CLAY: dark gray (10yr 4/1), trace silt, poorly sorted gravel, stiff, moist		Refusal @ 9' - Redrill
					GRAVEL: Poorly sorted, moist, loose		
-10		GP	50 (8'				

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
			to 12')				
		CL			SANDY CLAY: olive (5 y 5/3), wet, medium stiff, poorly sorted gravel, water		
-12							
	5.2 ppm @ 12.5'	SW			GRAVELLY SAND: wet, loose		Water Sample WP-FAAB-SB03-GW01 12'-16'
			90 (12' to 16')		CLAY: black (10yr 2/1), trace silt, stiff, moist, some staining and some poorly sorted gravel		
-14							
		CL					
-16	4 ppm @ 16'				CLAY: dark brown (10yr 3/3), trace silt, stiff, moist		
-18							
	3.8 ppm @ 19.2'		75 (16' to 20')				
-20							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO:	VW03/SB04
TOTAL DEPTH:	22'
FILE NAME:	RWP-VW03-SB04

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	9-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLER:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: SB04 was converted to VW03 on 10-13-99 using H.S.A. methods.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
2							
					Topsoil		5.8 ppm bkg
	15.2 ppm @ 0.5'		100 (0' to 4')		CLAY: with poorly sorted gravel, medium stiff, moist		Soil Sample WP-FAAB-SB04-SS01 0.0'-0.5'
-2		CL			CLAY: dark yellowish brown (10yr 3/4) clay, trace silt, very stiff, moist, some staining @ 4'		Riser and screen - schedule 40 PVC
	10.5 ppm @ 3'						
-4	11 ppm @ 5'				CLAY: black (10yr 2/1), trace silt, mottled, poorly sorted gravel, stiff, moist		Soil Sample WP-FAAB-SB04-SS02 4'-8'
-6			100 (4' to 8')				
-8							
-10	8.8		100		SANDY CLAY: dark gray		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
	ppm @ 10'	GP	(8' to 12')		(10yr 3/6) with poorly sorted gravel, medium stiff, moist		
-12		SP			GRAVEL AND SAND: sand and poorly sorted gravel, wet, loose		Water Sample WP-FAAB-SB04-GW01 12'-16'
-14	8.9 ppm @ 14'	CL	100 (12' to 16')		CLAY: black (10yr 2/1), mottled, stiff, moist, traces of poorly sorted sand and gravel and silt		
-16							
-18	11.2 ppm @ 18'		100 (16' to 20')				
-20			100 (20' to 22')				
-22	11.2 ppm @ 21'						

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO:	SB05
TOTAL DEPTH:	22'
FILE NAME	RWP-SB05

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Well was backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0	15.6 ppm @ 0.2'				Topsoil		5.4 ppm bkg Soil Sample WP-FAAB-SB05-SS01 0.0'-0.5'
					CLAY: dark yellowish brown (10yr 4/6) to brown (10yr 5/3), trace silt and poorly sorted gravel, stiff to medium stiff, moist, trace organics at 3.5-feet, mottling after 8-feet		
-2		CL					
			100 (0' to 4')				Soil Sample WP-FAAB-SB05-SS02 0.5'-4'
-4	11.0 ppm @ 4'						Soil Sample WP-FAAB-SB05-SS52 0.5'-4'
-6			100 (4' to 8')				
-8							
-10	8.2 ppm @ 10'		100 (8' to 12')				Water Sample WP-FAAB-SB05-GW01 12'-14'
					GRAVELLY SAND: poorly sorted, wet, loose		
-12		SP					
		SP					Water Sample WP-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14	9.7 ppm @14'		40 (12' to 16')				FAAB-SB05-GW51 12'-14'
		CL			CLAY: gray (10yr 6/1), trace silt, mottled, stiff, moist		
-16					CLAY AND SILT: with sand, medium stiff, moist		
-18	10.7 ppm @ 18'		100 (16' to 20')		CLAY: yellowish brown (10yr 5/6), trace silt, mottled, trace poorly sorted gravel, stiff, moist		
-20					SILTY CLAY: mottled, trace poorly sorted gravel, soft, moist		
	10.9 ppm @ 21'		100 (20' to 24')				
-22							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB06
TOTAL DEPTH: 20'
FILE NAME RWP-SB06

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Well was filled in with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		5.8 ppm bkg
	12.6 ppm @ 0.5'	SP			GRAVEL AND SAND: loose and moist		Soil Sample WP-FAAB-SB06-SS01 0.0'-0.5'
-2		CL	100 (0' to 4')		CLAY: dark yellowish brown (10yr 3/6), trace silt mottled, stiff, moist		Soil Sample WP-FAAB-SB06-SS02 0.5'-4'
-4	11.3 ppm @ 4'	SP			GRAVELLY SAND: Poorly sorted, loose, moist		
-6			100 (4' to 8')				
		CL			CLAY: yellowish brown (10yr 5/4) clay, trace silt, stiff, moist, mottled		
-8	11.1 ppm @ 8'				SILTY CLAY: dark grayish brown (10yr 4/2), poorly sorted gravel, soft, moist		Water Sample WP-FAAB-SB06-GW01 8'-12'
-10			100 (8' to 12')				
		SP			GRAVEL AND SAND: wet, loose		
-12		CL			CLAY: yellowish brown (10yr 5/4), trace silt, stiff, moist, mottled		
	11.6 ppm @ 12.5'	CL					1.2 ppm bkg

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
.4			10 (12' to 16')		SILTY CLAY: gray (10 yr 5/1) trace poorly sorted gravel, soft, moist		
-16	4.1 ppm @16'				SILTY CLAY: gray (10yr 6/1), trace sand, soft, moist, mottled		
-18	3.9 ppm @ 19.4'		90 (16' to 20')				
-20							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: VW01/SB07
TOTAL DEPTH: 22'
FILE NAME: RWP-VW01-SB07

PROJECT INFORMATION

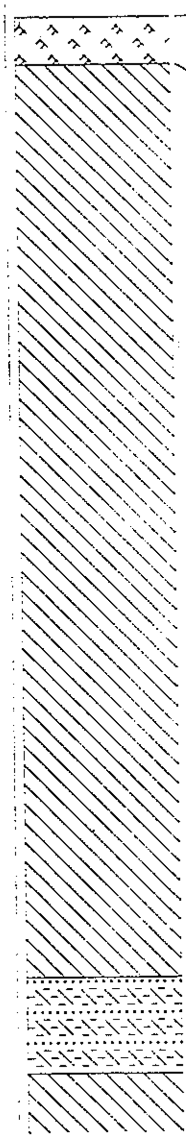
PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 09-29-99

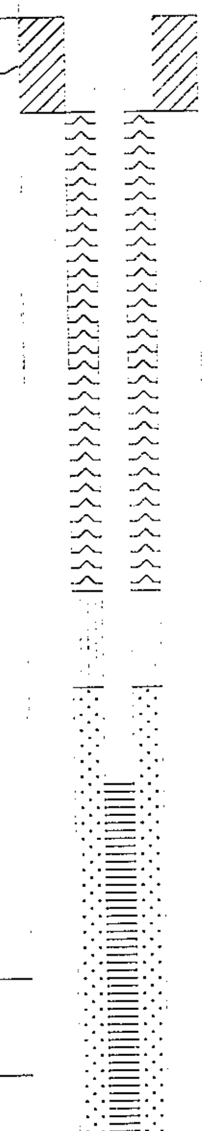
DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD: 4-foot direct push method

NOTES: SB07 was converted to VW01 on 10-13-99

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
2							
0					Topsoil		1.0 ppm bkg
	3.9 ppm @ 0.5'				CLAY: dark grayish brown (10yr 4/2) trace silt, poorly sorted gravel,medium stiff, mottled, moist		Soil Sample WP-FAAB-SB07-SS01 0.0'-0.5'
-2			100 (0' to 5')				
		CL					Soil Sample WP-FAAB-SB07-SS02 0.5'-4'
-4	3.5 ppm @ 4'						
-6							
			100 (5' to 12')				
-8	3.3 ppm @ 8'						Water Sample WP-FAAB-SB07-GW01 8'-12'
-10					CLAY AND SAND: poorly sorted gravel, wet, loose		
					CLAY: very dark grayish brown (10yr 3/2), trace sand and silt, stiff, moist, mottled		





DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-12	3.3 ppm @ 12.5'	CL			SILTY CLAY: gray (10yr 5/1), poorly sorted gravel, medium stiff, moist		
-14		CL	100 (12' to 17')		CLAY: dark gray (10yr 4/1) to very dark gray (10yr 3/1), trace silt, trace gravel, stiff, moist, mottled		
-16	3.1 ppm @ 16'						
-18			100 (17' to 22')				
-20	2.3 ppm @ 20'						Discrete sample @ 20'
-22							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO:	SB07 / VW01
TOTAL DEPTH:	22'
FILE NAME	RWP-SB07

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES:

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		1.0 ppm bkg
	3.9 ppm @ 0.5'				CLAY: dark grayish brown (10yr 4/2), trace silt and poorly sorted gravel, medium stiff, moist, mottled		Soil Sample WP-FAAB-SB07-SS01 0.0'-0.5'
-2			100 (0' to 4')				Soil Sample WP-FAAB-SB07-SS02 0.5'-4'
		CL					
-4	3.5 ppm @ 4'						
-6							
			100 (4' to 8')				
-8	3.3 ppm @ 8'						Water Sample WP-FAAB-SB07-GW01 8'-12'
-10					CLAY AND SAND: poorly sorted gravel, wet, soft		
					CLAY: very dark grayish brown (10yr 3/2), trace sand and silt, stiff, moist, mottled		
-12		CL			SILTY CLAY: gray (10yr 5/1), poorly sorted gravel, soft, moist		
	3.3 ppm @ 12.5'						

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14		CL	100 (12' to 16')		CLAY: dark gray (10yr 4/1), trace silt, trace gravel, stiff, moist, mottled		
-16	3.1 ppm @16'						
-18							
			100 (16' to 20')				Discrete sample @ 20'
-20	2.3 ppm @ 20'						
-22							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	SB08 / IN02
TOTAL DEPTH:	24'
FILE NAME	RWP-SB08

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES:

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		1.0 ppm bkg
	3.3 ppm @0.5'				CLAY: dark brown (10yr 3/3), trace sand and silt, stiff, moist, mottled below 8'		
-2			90 (0' to 4')				
		CL					
-4	4.9 ppm @ 4'						Soil Sample WP-FAAB-SB08-SS01 4'-8'
-6							
			100 (4' to 8')				
-8	98.7 ppm @ 8'	CL					Soil Sample WP-FAAB-SB08-SS02 8'-12'
							Refusal at 9', rebore 3' east
-10							
					GRAVEL: large, moist		
		GP			GRAVELLY SAND: poorly sorted, wet, loose		
-12							
	110 ppm @ 12.5'						Water Sample WP-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14			30 (12' to 16')				FAAB-SB08-GW01 12'-16'
-16	3.9 ppm @ 16'						
					SILTY CLAY: very dark grayish brown (10yr 3/2), medium soft, moist, trace small poorly sorted gravel		
-18		CL	100 (16' to 20')				
-20	3.1 ppm @ 20'						
-22							
	2.7 ppm @ 23.4'		100 (20' to 24')				
-24							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB09
TOTAL DEPTH: 24'
FILE NAME RWP-SB09

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 09-30-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: Well backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil: with large gravel pieces		0.3 ppm bkg Soil Sample WP-FAAB-SB09-SS01 0.0'-0.5'
	2.6 ppm @ 0.5'				CLAY AND SILT: dark brown (10yr 3/3), poorly sorted gravel, loose, moist		
-2		CL	100 (0' to 4')				Soil Sample WP-FAAB-SB09-SS02 0.5'-4'
-4	2.8 ppm @ 4'				CLAY: dark yellowish brown (10yr 3/4), trace silt, poorly sorted gravel, stiff, moist, mottled below 8'		
-6			90 (4' to 8')				
-8	1.7 ppm @ 8'						
-10			90 (8' to 12')				
		CL					
-12					CLAY: black (10yr 2/1), mottled		
	1.9 ppm @ 12.5'						Water Sample WP-FAAB-SB09-GW01 12'-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
							16'
		SP	40 (12' to 16')		GRAVELLY SAND: wet, loose		
-16	2.1 ppm @ 16'	CL			SILTY CLAY: black (10yr 2/1), some poorly sorted gravel, medium stiff, moist		
-18			100 (16' to 20')				
-20	1.2 ppm @ 20'						
					SILTY CLAY: black (10yr 2/1), some poorly sorted gravel, stiff, moist		
-22			100 (20' to 24')				
	0.9 ppm @ 23.5'						
-24							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: IN01/SB10
TOTAL DEPTH: 24'
FILE NAME: RWP-IN01-SB10

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 09-30-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLER: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: SB10 converted to IN01 using hollow stem auger methods

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		
	1.0 ppm @ 0.5'	CL			CLAY: very dark gray (10yr 3/1), trace silt, poorly sorted gravel, stiff, moist, mottled after 8'		SB10 was overdrilled on 10-7-99 and converted to IN01.
-2			80 (0' to 4')				Riser - black iron, 4' stainless steel screen.
-4	2.1 ppm @ 4'						Soil Sample WP-FAAB-SB10-SS01 4'-8'
-6			90 (4' to 8')				
-8	8.3 ppm @ 8'						Soil Sample WP-FAAB-SB10-SS02 8'-12'
-10			100 (8' to 12')				
-12							

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
	3.8 ppm @ 12.5'	CL					
-14		SP	90 (12' to 16')		GRAVEL AND SAND: wet, loose		Water Sample WP-FAAB-SB10-GW01 14'
-16	0.3 ppm @ 16'	CL			SILTY CLAY: very dark grayish brown (10yr 3/2) silty, soft, moist, trace poorly sorted gravel		
-18			90 (16' to 20')				
-20	0.5 ppm @ 20'						
-22	0.3 ppm @ 23.5'		90 (20' to 24')		CLAY: dark yellowish brown (10yr 4/6), trace silt and poorly sorted gravel, Iron staining, medium stiff, moist		
-24							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: VW04/SB11
TOTAL DEPTH: 24'
FILE NAME: RWP-VW04-SB11

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-30-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLER:	T. Setty
RIG TYPE:	5400
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: VW04 was installed approx. 2' from SB11 on 10-13-99.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
2							VW04 was installed using hollow stem auger method
					GRAVEL: Fill		Riser and screen - schedule 40 PVC
	8.3 ppm @ 0.5'				CLAY: brown (10yr 4/3), trace silt, poorly sorted gravel, medium stiff, moist		
-2			90 (0' to 4')				Soil Sample WP-FAAB-SB11-SS02 0.5'-4'
		CL					
-4	25.3 ppm @ 4'						Soil Sample WP-FAAB-SB11-SS01 4'-8'
-6			100 (4' to 8')				
					CLAY: gray (10yr 5/1), trace silt and poorly sorted gravel, mottled, stiff, moist		
	27.2 ppm @ 8'						
-10			100				

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
			(8' to 12')				
-12	6.6 ppm @ 12.5'						Water Sample WP-FAAB-SB11-GW01 12'-16'
-14			50 (12' to 16')		SANDY GRAVEL: poorly sorted gravel, loose, wet		
		GP			CLAY: very dark grayish brown (10yr 3/2), trace silt and poorly sorted gravel, stiff, moist		
-16	5.4 ppm @ 16'						
-18			100 (16' to 20')		SILTY CLAY: very dark brown (10yr 2/2), soft, moist		
-20	0.1 ppm @ 20'	SP			SAND: 1 " of loose sand, moist		
		CL			CLAY: black (10yr 2/1) trace silt, stiff, moist		
-22			100 (20' to 24')				
	0.2 ppm @ 23.3'				CLAY: dark yellowish brown (10yr 4/6), trace silt and poorly sorted gravel, soft, moist, mottled		
-24							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	SB12
TOTAL DEPTH:	24'
FILE NAME	RWP-SB12

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	J. McBride
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-04-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Wells backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					GRAVEL: very dark grayish brown (10yr 3/2) gravel fill, sand and silty, moist		2.4 ppm bkg Soil Sample WP-FAAB-SB12-SS01 0'-4'
-2	5.5 ppm 2'	CL	64 (0' to 4')		SILTY CLAY: gray (10yr 5/1) to light gray (10yr 7/2) with sand and fine gravel, moist		
-4							Soil Sample WP-FAAB-SB12-SS02 4'-8'
-6	5.1 ppm @ 6'		85 (4' to 8')				
-8							Soil Sample WP-FAAB-SB12-SS03 8'-12'
	4.9 ppm @ 9'						
-10			50 (8' to 12')				
					SAND: very dark grayish brown (10yr 3/2) sand with angular gravel, trace silt and clay, wet		
-12							Water Sample WP-FAAB-SB12-GW01 8'-
		CL			SILTY CLAY: dark gray (10yr 4/1) trace angular		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
					gravel, trace fine sand, wet and moist		12'
-14	5.9 ppm @ 14'		27 (12' to 16')				
-16							
-18	4.9 ppm @ 18'		87 (16' to 20')				
-20	5.7 ppm@ 20'						
							Shoe Lost Hole abandonded
-22			62 (20' to 24')				
-24							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB13
TOTAL DEPTH: 30'
FILE NAME RWP-SB13

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: J. McBride
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-04-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: Wells backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					SILTY CLAY: light gray to dark brown (10yr 7/2 to 10yr 4/1), medium dense, trace to some fine angular gravel and fine sand, moist		2.7 ppm bkg
-2	4.3 ppm @ 2'		60 (0' to 4')				Soil Sample WP-FAAB-SB13-SS01 0'-4'
-4							Soil Sample WP-FAAB-SB13-SS02 4'-8'
	4.1 ppm @ 5'	CL					
-6			81 (4' to 8')				
-8							Soil Sample WP-FAAB-SB13-SS03 8'-12'
-10	4.2 ppm @ 10'		83 (8' to 12')		SAND: grayish brown (10yr 5/2) fine sand with some fine gravel (subangular), moist		
		SP					
					SILTY CLAY: brown (10yr 4/3) trace fine sand and fine gravel, moist, stiff		
-12		CL					

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14	3.9 ppm @ 14'	CL					
			73 (12' to 16')				No water in rod at 16'
-16							
-18	5.9 ppm @ 18'						
-20							Soil Sample WP-FAAB-SB13-SS04 20'-22'
			100 (16' to 20')				
-22	13.1 ppm @ 22'						
		ML	100 (20' to 24')				
					SILT: light gray (10yr 7/2) hard silt		
-24	3.8 ppm @ 24'						
	3.1 ppm @ 25'						
-26			100 (24' to 26')				
	3.2 ppm @ 27'		100 (26' to 30')		SAND: light gray (10yr 7/2) fine with fine gravel and some clayey silt, wet at 28.5'		Water Sample WP-FAAB-SB13-GW01 28'
-28							
					BEDROCK		
-30							

IT CORPORATION	**FIELD BOREHOLE LOG** BOREHOLE NO: **SB14** TOTAL DEPTH: **28'** FILE NAME **RWP-SB14**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**FAA-B**	DRILLING CO:	**AST**
SITE LOCATION:	**WPAFB, OH**	DRILLERS:	**T. Setty**
JOB NUMBER:	**781791**	RIG TYPE:	**5400 Model**
LOGGED BY:	**J. McBride**	METHOD OF DRILLING:	**Geoprobe**
PROJECT MANAGER:	**R. Sinha**	SAMPLING METHOD	**4-foot direct push method**
DATE DRILLED:	**10-05-99**		

NOTES: Wells backfilled bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					GRAVEL: loose, coarse gravel fill		1.2 ppm bkg
		CL			SILTY CLAY: (FILL) brown (10yr 5/3) medium stiff, with some fine sand and fine gravel, moist		
-2	8.2 ppm @ 2'		62 (0' to 4')				Soil Sample WP-FAAB-SB14-SS01 0'-4'
-4							Soil Sample WP-FAAB-SB14-SS02 4'-8'
					SILTY CLAY: light gray (10yr 7/2) medium stiff to stiff, with little fine sand and trace fine gravel, angular, moist		
-6	39.7 ppm @ 6'		42 (4' to 8')				
-8							Soil Sample WP-FAAB-SB14-SS03 8'-12'
-10	15.6 ppm @ 10'						
-12							
		CL					

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14	8.7 ppm @ 14'		100 (12' to 16)		SILTY SAND: gray (10yr 5/1) medium dense fine silty sand, wet		Water Sample WP-FAAB-SB14-GW01 14.1'
		CL			SILTY CLAY: dark yellowish brown (10yr 4/6) stiff, with some fine sand, and trace fine gravel, moist		
-16							
	7.5 ppm @ 17'		100 (16' to 18')				
-18							
	7.5 ppm @ 19'		100 (18' to 20')				
					SILTY SAND: very dark gray (10yr 3/1) fine silty sand, wet		
-20							Water Sample WP-FAAB-SB14-GW02 20'
					SILTY CLAY: gray (10yr 5/1) stiff, with some fine to medium sand, moist		
	4.5 ppm @ 21'		100 (20' to 22')				
-22							
	7.1 ppm @ 23'		100 (22' to 24')				
-24	5.9 ppm @ 24'		100 (24' to 25')				
	6.2 ppm @ 25'	CL					
-26			100 (25' to 28')				Water Sample WP-FAAB-SB14-GW03 26'-28'
					GRAVEL: light gray (10yr 5/2) fine to coarse gravel with some fine to medium sand, with some silt and clay, wet		
		GC					
-28							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	SB15
TOTAL DEPTH:	38'
FILE NAME	RWP-SB15

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	J. McBride
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-05-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Wells backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		
					SAND: light gray (10yr 7/2) medium dense, fine to medium sand, some angular gravel and little silt and clay, moist		
-2		SP	81 (0' to 4')				
	1.9 ppm @ 3'						
-4							
-6	1.7 ppm @ 6'		70 (4' to 8')				
-8							Soil Sample WP-FAAB-SB15-SS01 8'-12'
					SILTY CLAY: light olive gray (5yr 6/2), with some sand, and angular gravel, moist		
-10	1.9 ppm @ 10'	CL	79 (8' to 12')				
-12					SILTY CLAY: black (5y 2.5/1) organic rich silt and clay, moist, wet at 14'		
		CL					

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14	1.1 ppm @ 14'		80 (12' to 16')				
							Water Sample WP-FAAB-SB15-GW01 15'-16'
-16					SILTY CLAY: light gray (10yr 6/2) to very dark gray (2.5y 3/1), medium stiff to stiff, with trace to little fine sand, moist		
-18			85 (16' to 20')				
	2.9 ppm @ 19"						
-20							
-22	1.1 ppm @ 22'		27 (20' to 24')				
-24							
-26		CL	77 (24' to 28')				
	0.9 ppm @ 27'				SILTY SAND: grayish brown (2.5y 5/2) fine silty sand, trace gravel, wet		Water Sample WP-FAAB-SB15-GW02 27'-28'
-28		SM			SILTY CLAY: very dark gray (2y 3/1), organic rich, stiff, moist		
					SILTY CLAY: light olive brown (2.5y 5/6) very stiff, with trace fine sand, moist		
-30	2.2 ppm @ 30'	CL	85 (28' to 32')				
-32							

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-34	3.3 ppm @ 34'		96 (32' to 38')				
					SILTY CLAY: gray (2.5y 5/2), very stiff, trace sand, moist, trace gravel		
-36							
	5.8 ppm @ 37'	CL					Bedrock @ 38'
-38							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB16
TOTAL DEPTH: 35.8'
FILE NAME RWP-SB16

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: J. McBride
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-05-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: Wells backfilled with bentonite chips at completion

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		
					SAND: light olive brown (2.5y 5/6) loose, fine to medium sand, with some fine to coarse gravel and little silt and clay, moist		
-2		SP	77 (0' to 4')				
-4	2.8 ppm @ 4'						
-6			60 (4' to 8')		GRAVEL AND SAND: light gray (10yr 7/2) medium dense, fine to medium sand and fine gravel, with little silt and clay, moist		
	2.6 ppm @ 7'						
-8							
-10			70 (8' to 12')				
	3.2 ppm @ 11'				SILTY CLAY: dark grayish brown (2.5y 4/2) stiff silty clay, trace fine to medium sand, moist		
-12		CL					
		CL					Soil Sample WP-FAAB-SB16-SS01 12'-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14			77 (12' to 16')				16'
	2.1 ppm @ 15'						
-16					SILTY SAND: dark grayish brown (2.5y 4/2) medium dense, fine silty sand, wet		
-18		SM	48 (16' to 20')				Water Sample WP-FAAB-SB16-GW01 18'-20'
	2.8 ppm @ 19'				SILTY CLAY: light olive gray (2.5y 5/3) sandy, silty clay, moist, medium stiff		
-20		CL					
-22	2.7 ppm @ 22'		44 (20' to 24')				
					SILTY SAND: light olive gray (2.5y 5/3) silty sand, wet, medium dense		
-24		SM					
					SILTY CLAY: black to very dark gray (5y 3/1), organic rich, stiff to hard, moist		
-26	3.1 ppm @ 26'	CL	85 (24' to 28')				Water Sample WP-FAAB-SB16-GW02 26'-28'
-28							
-30			79 (28' to 32')				
	5.1 ppm @ 31'						
-32							

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
			100 (32' to 35.8')				
34	4.8 ppm @ 34'						Bedrock @ 35.8'
	3.6 ppm @ 35'						

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB17
TOTAL DEPTH: 36'
FILE NAME RWP-SB16

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	J. McBride
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-06-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Hole backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		
					SAND: pale brown (10yr 6/2) medium dense, fine to medium sand with some fine to medium gravel (fill), moist		
-2	9.2 ppm @ 2'	SP	79 (0' to 4')				
-4							
-6	4.5 ppm @ 6'		85 (4' to 8')				
-8							
-10			79 (8' to 12')				
					SILTY CLAY: black (10yr 2/1) medium stiff, silty clay (organic rich) damp		
	4.1 ppm @ 11'	OL					
-12							
		OL					Soil Sample WP-FAAB-SB17-SS01 12'-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-14	2.1 ppm @ 14'		79 (12' to 16')				16'
					SILTY SAND: grayish brown (10yr 5/2) fine silty sand, wet, medium dense		Water Sample WP-FAAB-SB17-GW01 15'-16'
-16		SM					
-18	3.3 ppm @ 18'		92 (16' to 20')				
		ML			SILTY CLAY: brown (10yr 4/3), some sand, trace coarse gravel, damp, medium stiff		
-20							
-22	2.8 ppm @ 22'		85 (20' to 24')				
-24		SM					
		SM			SILTY SAND: very dark grayish brown (10yr 3/2) fine to medium silty sand, medium dense, wet		Water Sample WP-FAAB-SB17-GW02 24'-25'
					SILTY CLAY: dark yellowish brown (10yr 4/4) to gray (10yr 5/1) stiff, dense to hard, with little fine sand, moist		
-26	4.7 ppm @ 26'		91 (24' to 28')				
		CL					
-28							
	7.1 ppm @ 29'						
-30			75 (28' to 32')				
-32	6.1 ppm @ 32'						

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-34	4.8 ppm @ 34.4		75 (32' to 36')				
-36							Bedrock @ 36'

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: SB18
TOTAL DEPTH: 28.2
FILE NAME RwP-SB18

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: J. McBride
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-06-99

DRILLING INFORMATION

DRILLING CO: AST
DRILLERS: T. Setty
RIG TYPE: 5400 Model
METHOD OF DRILLING: Geoprobe
SAMPLING METHOD 4-foot direct push method

NOTES: Hole backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		
		SM			SAND: brown (10yr 5/3) loose fine to medium sand, moist		
-2			77 (0' to 4')		SILTY CLAY: very dark grayish brown (10yr 3/2) with trace fine sand, moist, medium stiff		Soil Sample WP-FAAB-SB18-SS01 0'-4'
		CL					
-4	2.1 ppm @ 4'						Soil Sample WP-FAAB-SB18-SS02 4'-8'
					SILTY CLAY: yellowish brown (10yr 5/6) medium stiff, with fine sand and trace of gravel, moist		
-6	2.1 ppm @ 6'		83 (4'to 8')				
-8							Soil Sample WP-FAAB-SB18-SS03 8'-12'
-10			100 (8' to 12')				
	1.7 ppm @ 11'						
-12							Soil Sample WP-FAAB-SB18-SS04 12'-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
							16'
4	1.8 ppm @ 14'	CL					
			100 (12' to 16')				
-16							Water Sample WP-FAAB-SB18-GW01 16'-18'
					SILTY SAND: brown (7.5 yr 5/4) fine to coarse sand, with fine gravel, medium dense, wet		
		SM					
-18							
					SILTY CLAY: brown (7.5yr 4/4) stiff, fine sand and fine to coarse gravel, moist		
	3.2 ppm @ 19'		79 (16' to 20')				
-20		CL					
			100 (20' to 22')		SILTY CLAY: gray (10yr 6/1) stiff, with little fine to medium sand and little fine to coarse gravel, moist		
-22							
	2.2 ppm @ 23'	SM	100 (22' to 25')				Water Sample WP-FAAB-SB18-GW02 23'-28'
					SAND: 2" sand lense		
-24							
					SILTY CLAY: gray (10yr 6/1) stiff, with little fine to medium sand and little fine to coarse gravel, moist		
	2.3 ppm @ 25'						
-26		CL	100 (25' to 28.2')				Bedrock @ 28.2'
	2.7 ppm @ 27'						
-28							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	SB19
TOTAL DEPTH:	24'
FILE NAME	RWP-SB19

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	J. McBride/ P. McCarren
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-06-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES : Hole backfilled with bentonite chips at completion.

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL: Topsoil		
					SILTY SAND: brown (10yr 4/3) loose fine to medium silty sand, fine to coarse gravel, moist		
-2	7.6 ppm @ 2'	SM	87 (0' to 4')				Soil Sample WP-FAAB-SB19-SS01 0'-4'
-4					SILTY CLAY: yellowish brown (10yr 5/4) medium stiff, fine to medium sand, trace fine to coarse gravel, moist		Soil Sample WP-FAAB-SB19-SS02 4'-8'
		CL					
-6	5.9 ppm @ 6'		100 (4' to 8')				
-8							Soil Sample WP-FAAB-SB19-SS03 8'-12'
-10	7.0 ppm @ 10'				SILTY CLAY: gray (10yr 6/1) medium stiff, with little fine sand, trace coarse gravel, moist to damp		
			100 (8' to 12')				
-12							Soil Sample WP-FAAB-SB19-SS04 12'-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
	7.2 ppm @ 14'		100 (12' to 24')				16'
-16							
-18	4.9 ppm @ 18'						
-20							Water Sample WP-FAAB-SB19-GW01
-22	6.1 ppm @ 22'						
-24					BEDROCK: Bedrock @ 24'		

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO:	MW07
TOTAL DEPTH:	28'
FILE NAME	RWP-MW07.dat

PROJECT INFORMATION

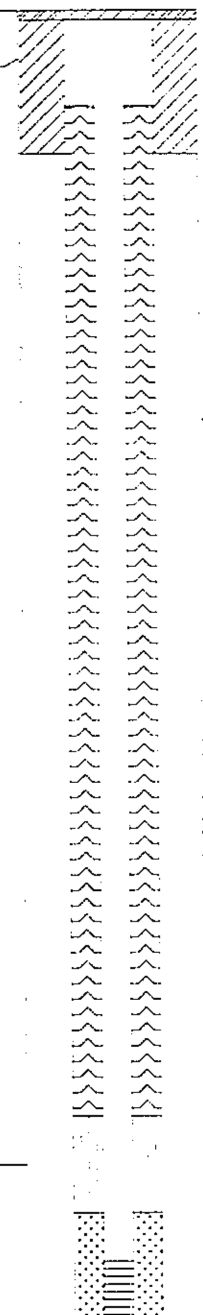
PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-4-99

DRILLING INFORMATION

DRILLING CO:	FORE Testing
DRILLERS:	R. Bender & T. Melton
RIG TYPE:	D-50
METHOD OF DRILLING:	Hollow stem auger
SAMPLING METHOD	2-' long, 2-" diam. split spoon sampler

NOTES: Riser - black iron, 10' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		
					CLAY: dark yellowish brown (10yr 3/6), trace silt, poorly sorted gravel, stiff, moist, mottled below 4'		
			70 (0.5' to 2')				
-2							
			80 (2' to 4')				
-4							Soil Sample WP-SP11-MW07-SS01 4' - 8'
			80 (4' to 6')				
-6		CL					
			90 (6' to 8')				
-8							Soil Sample WP-SP11-MW07-SS02 8' - 12'
			100 (8' to 10')				
-10							
			40 (10' to 12')				
-12					SANDY CLAY: dark brown (10yr 3/3), with silt and poorly sorted gravel, soft, moist		
		CL	50 (12' to 14')				



DEPTH	PID ppm	USCS	[redacted] RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
		SP	80 (14' to 16')		GRAVEL AND SAND: coarse grain, loose, wet		Water Sample WP-SP11-MW07-GW01 14'
-16			100 (16' to 18')		CLAY: dark yellowish brown (10yr 4/4), trace silt and poorly sorted gravel, mottled, very stiff, moist		
-18		CL	100 (18' to 20')		SILTY CLAY: very dark grayish brown (10yr 3/2), and poorly sorted gravel, moist, soft		
-20		CL	100 (20' to 22')		CLAY: black (10yr 2/1), trace silt and organics, stiff, moist		
-22			20 (22' to 24')				
					SANDY CLAY: fine grain, poorly sorted gravel, wet, soft		
-24			100 (24' to 26')		SILTY CLAY: very dark grayish brown (10yr 3/2), soft, moist		
					CLAY: dark yellowish brown (10yr 4/6), trace silt, stiff, moist		
-26		CL			SILTY SAND: loose, wet		Bentonite Filled
			40 (26' to 28')		CLAY: dark yellowish brown (10yr 4/4), trace silt, stiff, moist		
-28			75 (28')		BEDROCK: Shale		

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: MW08
TOTAL DEPTH: 34.5
FILE NAME RWP-MW08

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-5-99

DRILLING INFORMATION

DRILLING CO:	FORE Testing
DRILLERS:	R. Bender & T. Melton
RIG TYPE:	D-50
METHOD OF DRILLING:	Hollow stem auger
SAMPLING METHOD	2-' long, 2-" diam. split spoon sampler

NOTES: Riser - black iron, 10' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		
					CLAY: brownish yellow (10yr 6/6), trace silt, poorly sorted gravel, stiff, moist, iron staining and mottled around 4-ft, mottled after 10-ft		0.9 ppm bkg
			80 (0.5' to 2')				
-2							Soil Sample WP-SP11-MW08-SS01 0 - 4'
	7.2 ppm @ 3'		90 (2' to 4')				
-4		CL					
			50 (4' to 6')				
-6							
			50 (6' to 8')				
-8	6.3 ppm @ 7.5'						
			10 (8' to 10')				
-10							
			100 (10' to 12')				
-12	6.0 ppm @ 11.5'						Soil Sample WP-SP11-MW08-SS02 12' - 16'
			90 (12' to 14')				

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
4							
			10 (14' to 16')				
-16	7.0 ppm @ 15.5'	CL					
			80 (16' to 18')				
-18							
			40 (18' to 20')				
-20	2.7 ppm @ 19.5'						
			40 (20' to 22')				
-22							
			100 (22' to 24')				
-24	2.4 ppm @ 23.5'	CL					
			100 (24' to 26')				
-26					SILTY CLAY: soft, moist		
			90 (26' to 28')		GRAVEL AND SAND: loose, wet		
-28	10.3 ppm @ 27.5'				CLAY: dark yellowish brown (10yr 4/4), trace silt and coarse grain sand, stiff, moist, mottled		Water Sample WP-SP11-MW08-GW01 27'
					SILTY CLAY: dark yellowish brown (10yr 4/6), trace coarse sand and gravel, moist, soft		
			90 (28' to 30')				
-30					CLAY: dark yellowish brown (10yr 4/6), trace silt and coarse gravel, stiff, moist		
			100 (30' to 32')				
-32	4.6 ppm @ 31.5'				CLAY: dark gray (10yr 4/1), trace silt and coarse grain sand, stiff, moist, mottled		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-34 -	3.2 ppm @33'		100 (32' to 34')		BEDROCK		Bentonite Filled

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: MW09
TOTAL DEPTH: 24'
FILE NAME RWP-MW09

PROJECT INFORMATION

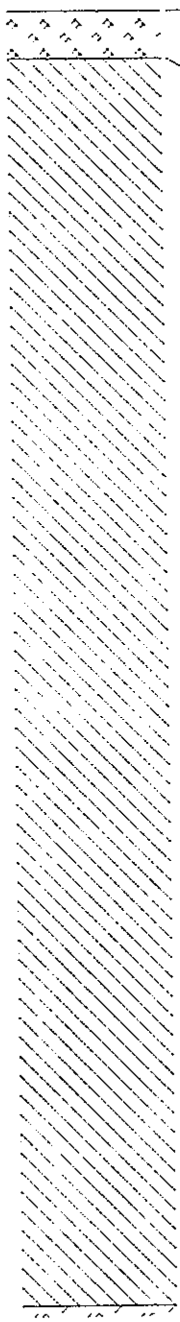
PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-6-99

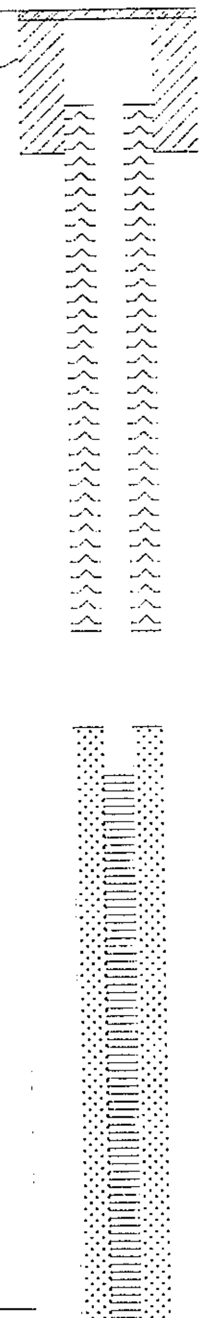
DRILLING INFORMATION

DRILLING CO: FORE Testing
DRILLERS: R. Bender & T. Melton
RIG TYPE: D-50
METHOD OF DRILLING: Hollow stem auger
SAMPLING METHOD 2-' long, 2-" diam. split spoon sampler

NOTES: Riser - black iron, 10' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		1.5 ppm bkg
					CLAY: yellowish brown (10yr 5/6), trace silt, poorly sorted gravel, soft, moist, mottled from 8 to 10 feet.		
			100 (1' to 2')				
-2	3.2 ppm @ 2'						
			80 (2' to 4')				
-4		CL					Soil Sample WP-SP11-MW09-SS02 4' - 8'
			90 (4' to 6')				
-6	3.5 ppm @ 6'						
			20 (6' to 8')				
-8							Soil Sample WP-SP11-MW09-SS01 8' - 12'
			70 (8' to 10')				
-10	4.1 ppm @ 10'						
		CL	70 (10' to 12')				
-12							
			60 (12' to 14')				





DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
4	4.8 ppm @ 14'				SANDY CLAY: gray (10yr 5/1), coarse grain sand and poorly sorted gravel, soft, moist (wet at 14')		Water Sample WP-SP11-MW09-GW01 14'
			50 (14' to 16')		SILTY CLAY: very dark grayish brown (10yr 3/2), and poorly sorted coarse sand, moist, soft		
-16			60 (16' to 18')		SILTY CLAY: gray (10yr 5/1), trace coarse sand and poorly sorted gravel, moist, soft		
-18	16.8 ppm @ 18'	CL	70 (18' to 20')		CLAY: dark yellowish brown (10yr 4/6), trace silt and poorly sorted coarse grain sand and gravel, stiff, moist		
-20					GRAVEL AND SAND: wet, loose		
			25 (20' to 22')		SILTY CLAY: very dark grayish brown (10yr 3/2), trace poorly sorted gravel,soft, moist, mottled		
-22	8.9 ppm @ 22'		30 (22' to 24')				Bentonite Filled
-24							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO:	IN02/SB08
TOTAL DEPTH:	24'
FILE NAME	RWP-IN02-SB08

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-29-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Riser - black iron, 5' stainless steel screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					Topsoil		1.0 ppm bkg
	3.3 ppm @ 0.5'				CLAY: dark brown (10yr 3/3), trace sand and silt, stiff, moist, mottled at 8'		SB08 was overdrilled on 10-7-99 and converted to IN02
-2			90 (0' to 4')				
		CL					
-4	4.9 ppm @ 4'						Soil Sample WP-FAAB-SB08-SS01 4'-8'
-6							
			100 (4' to 8')				
-8	98.7 ppm @ 8'	CL					Soil Sample WP-FAAB-SB08-SS02 8'-12'
							Refusal at 9', rebore 3' east
-10							
					GRAVEL: Seam large gravel, moist		
		GP			GRAVELLY SAND: poorly sorted, wet, loose		
-12							
	110 ppm @ 12.5'						Water Sample WP-

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-			30 (12' to 16')				FAAB-SB08-GW01 12'-16'
-16 -	3.9 ppm @16'						
					SILTY CLAY: very dark grayish brown (10yr 3/2), soft, moist, trace fine poorly sorted gravel		
-18 -		CL	100 (16' to 20')				
-20 -	3.1 ppm @ 20'						
-22 -							
	2.7 ppm		100 (20' to 24')				
-24 -	@						

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: IN03
TOTAL DEPTH: 18'
FILE NAME RWP-IN03

PROJECT INFORMATION

PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-7-99

DRILLING INFORMATION

DRILLING CO: FORE Testing
DRILLERS: R. Bender & T. Melton
RIG TYPE: D-50
METHOD OF DRILLING: Hollow stem auger
SAMPLING METHOD 2-' long, 2-" diam. split spoon sampler

NOTES: Riser - black iron, 4' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					GRAVEL		0.1 ppm bkg
			40 (1' to 2')		CLAY: dark yellowish brown (10yr 3/4) to gray (10yr 5/1), trace silt, poorly sorted gravel, coarse sand, stiff, moist, some iron staining at 4' and mottled after 6'		
-2	1.2 ppm @ 2'	CL					
			50 (2' to 4')				
-4							Soil Sample WP-FAAB-IW03-SS01 4' - 8'
			60 (4' to 6')				
-6	3.7 ppm @ 6'						
			100 (6' to 8')				
-8							Soil Sample WP-FAAB-IW03-SS02 8' - 12'
			80 (8' to 10')				
-10							
	3.2 ppm @ 11'	GP	40 (10' to 12')		SAND: and poorly sorted gravel, loose, moist		
-12							
			60 (12' to 14')		CLAY: very dark gray (10yr 3/1), trace silt and coarse grained sand, stiff, moist, mottled		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
4 –					SAND: and poorly sorted gravel, loose, wet		
	0.5 ppm @15'	CL	60 (14' to 16')		CLAY: very dark brown (10yr 2/2) trace silt and coarse grained sand, very stiff, moist		
–16 –					SANDY CLAY: with poorly sorted gravel moist, medium stiff		
	0.5 ppm @17'		70 (16' to 18')		CLAY: dark yellowish brown (10yr 4/6), trace silt and coarse sand, very stiff, moist, mottled		
–18 –							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	IN04/SB01
TOTAL DEPTH:	20'
FILE NAME	RWP-IN04-SB01

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	09-28-99

DRILLING INFORMATION

DRILLING CO:	AST
DRILLERS:	T. Setty
RIG TYPE:	5400 Model
METHOD OF DRILLING:	Geoprobe
SAMPLING METHOD	4-foot direct push method

NOTES: Riser - black iron, 4' stainless steel screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					TOPSOIL		0.0 ppm bkg
	3 ppm @ 1'				SILT: gray (10yr 6/1)moist, medium stiff, trace poorly graded gravel		Soil Sample WP-FAAB-SB01-SS01 0'-0.5'
-2		ML	60 (0' to 4')		CLAY: yellowish brown (10yr 5/4), trace silt and silt, moist, stiff		
							SB01 was overdrilled on 10-8-99 and converted to IN04
					GRAVEL: 1" seam large gravel at 3'5"		
-4	2 ppm @ 4'	CL			SILTY CLAY: gray (10yr 6/1) moist, medium stiff, with poorly graded gravel		
-6		OL	60 (4' to 8')				Soil Sample WP-FAAB-SB01-SS01 4'-8'
					CLAY: trace silt, moist, stiff		
-8	2.6 ppm @ 8'	OL			SILTY CLAY: gray (10yr 6/1) moist, medium stiff with poorly sorted gravel		
							Water Sample WP-FAAB-SB01-GW01 8'-12'
-10			50 (8' to 12')				
		GP			GRAVEL AND SAND: wet, loose		
-12	3.6 ppm @ 12'	CL			SANDY CLAY: black (10yr 2/1) moist, soft		
					GRAVEL: gray (10yr 5/1) some clay and large gravel, 0.5 - 3 cm, wet		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
-		CL	50 (12' to 16')		CLAY: grayish brown (10yr 5/2) trace silt, very stiff, moist, softer at 17.5'		
-16 -	1.6 ppm @ 16'						
		CL					
-18 -			70 (16' to 20')				
	3.2 ppm @ 19.5'						
-20 -							

IT CORPORATION

FIELD BOREHOLE LOG

BOREHOLE NO: IN05
TOTAL DEPTH: 16.1'
FILE NAME: RWP-IN05

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-8-99

DRILLING INFORMATION

DRILLING CO:	FORE Testing
DRILLERS:	R. Bender & T. Melton
RIG TYPE:	D-50
METHOD OF DRILLING:	Hollow stem auger
SAMPLING METHOD	2-' long, 2-" diam. split spoon sampler

NOTES : Riser - black iron, 5' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					GRAVEL		0.1 ppm bkg
			100 (1' to 2')		CLAY: dark yellowish brown (10yr 3/4), with silt, poorly sorted gravel, coarse sand, medium stiff, moist		
-2	0.5 ppm @ 2'						
			80 (2' to 4')				
-4							Soil Sample WP-FAAB-IW05-SS01 4' - 8'
			80 (4' to 6')				
-6	1.5 ppm @ 6'	CL					
			60 (6' to 8')				
-8							Soil Sample WP-FAAB-IW05-SS02 8' - 12'
			50 (8' to 10')				
-10	1.1 ppm @ 10'						
			20 (10' to 12')		GRAVEL AND SAND: poorly sorted, loose, wet		
-12		GP					
			30 (12' to 14')		CLAY: light gray (10yr 7/1), stiff, moist		Water Sample WP-

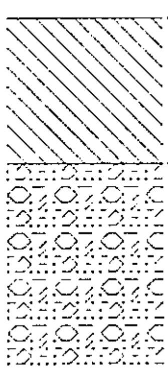
DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
		CL					FAAB-IW05 GW01 12' - 14'
	0.9 ppm @ 15'		30 (14' to 16')				
16							

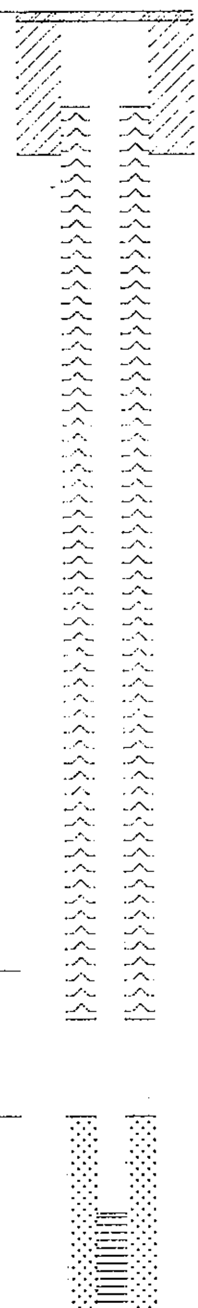
IT CORPORATION	**FIELD BOREHOLE LOG**
	BOREHOLE NO: IN06
	TOTAL DEPTH: 18'
	FILE NAME RWP-IN06

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	FAA-B	DRILLING CO:	FORE Testing
SITE LOCATION:	WPAFB, OH	DRILLERS:	R. Bender & T. Melton
JOB NUMBER:	781791	RIG TYPE:	D-50
LOGGED BY:	V. Voisard	METHOD OF DRILLING:	Hollow stem auger
PROJECT MANAGER:	R. Sinha	SAMPLING METHOD	2-' long, 2-" diam. split spoon sampler
DATE DRILLED:	10-11-99		

NOTES: Riser - black iron, 5' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					No samples collected or logged 0 - 10'		No samples were collected from 0 - 10'
-2							
-4							
-6							
-8							
-10		CL			CLAY: very dark gray (10yr 3/1), poorly sorted gravel, coarse sand, soft, moist		0.1 ppm bkg
	0.4 ppm @ 11'		60 (10' to 12')				Soil Sample WP-FAAB-IW06-SS01 11.5'
-12					GRAVEL AND SAND: poorly sorted, loose, wet, trace clay after 12.5-feet		Water Sample WP-FAAB-IW06 GW01 12'
	0.4 ppm		20 (12' to 14')				





DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
	@ 13'						
	0.4 ppm @ 15'		30 (14' to 16')		CLAY: gray (10yr 5/1), trace poorly sorted gravel and coarse sand, medium stiff, moist		
-16 -		CL					
	0.4 ppm @ 17'		50 (16' to 18')		CLAY: dark brown (10yr 3/3), trace silt and coarse sand, stiff, moist		
-18 -							

FIELD BOREHOLE LOG

BOREHOLE NO: IN07
TOTAL DEPTH: 18'
FILE NAME RWP-IN07

PROJECT INFORMATION

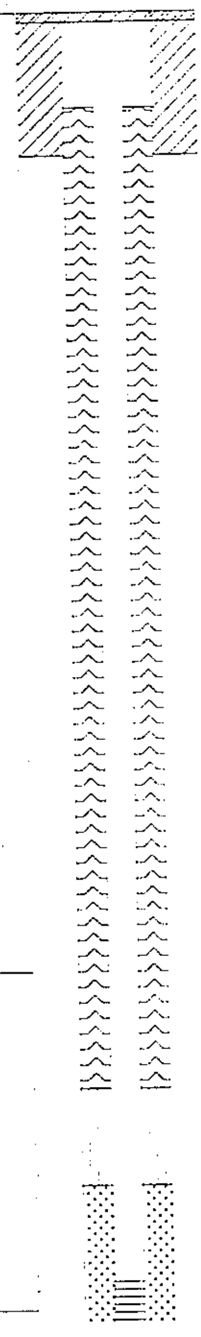
PROJECT: FAA-B
SITE LOCATION: WPAFB, OH
JOB NUMBER: 781791
LOGGED BY: V. Voisard
PROJECT MANAGER: R. Sinha
DATE DRILLED: 10-11-99

DRILLING INFORMATION

DRILLING CO: FORE Testing
DRILLERS: R. Bender & T. Melton
RIG TYPE: D-50
METHOD OF DRILLING: Hollow stem auger
SAMPLING METHOD 2-' long,2-" diam. split spoon sampler

NOTES: Riser - black iron, 4' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					No samples collected or logged 0 - 10'		No samples were collected from 0 - 10'
-2							
-4							
-6							
-8							
-10		CL			CLAY: dark grayish brown (10yr 4/2), trace silt, poorly sorted gravel, coarse grain sand, stiff, moist, mottled		0.1 ppm bkg
	0.9 ppm @ 11'		70 (10' to 12')				Soil Sample WP-FAAB-IW07-SS01 10' - 12'
-12							
	0.7 ppm		50 (12' to 14')				



DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
4	@ 13'				GRAVEL AND SAND: poorly sorted, loose, wet		
	0.6 ppm @ 15'		50 (14' to 16')		CLAY: dark grayish brown (10yr 4/2), trace silt, poorly sorted gravel, coarse grain sand, stiff, moist		
16		CL			CLAY: gray (10yr 6/1), trace silt and coarse grain sand, stiff, moist, mottled		
	0.4 ppm @ 17'		100 (16' to 18')				
18							

FIELD BOREHOLE LOG

IT CORPORATION

BOREHOLE NO:	IN08
TOTAL DEPTH:	18'
FILE NAME	RWP-IN08

PROJECT INFORMATION

PROJECT:	FAA-B
SITE LOCATION:	WPAFB, OH
JOB NUMBER:	781791
LOGGED BY:	V. Voisard
PROJECT MANAGER:	R. Sinha
DATE DRILLED:	10-12-99

DRILLING INFORMATION

DRILLING CO:	FORE Testing
DRILLERS:	R. Bender & T. Melton
RIG TYPE:	D-50
METHOD OF DRILLING:	Hollow stem auger
SAMPLING METHOD	2-' long, 2-" diam. split spoon sampler

NOTES: Riser - black iron, 5' stainless steal screen

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
0					No samples collected or logged 0 - 10'		No samples were collected from 0 - 10'
-2							
-4							
-6							
-8							
-10		CL			CLAY: very dark brown (10yr 2/2), trace silt and fine grain sand, stiff, moist		0.1 ppm bkg
	0.4 ppm @ 11'		80 (10' to 12')				Soil Sample WP-FAAB-IW08-SS01 10' - 12'
-12							
	0.4 ppm		60 (12' to 14')				
					GRAVEL AND SAND: poorly sorted, loose, wet		

DEPTH	PID ppm	USCS	% RECOVERY	LITHOLOGY	LITHOLOGICAL DESCRIPTION	WELL CONSTRUCTION	NOTES
	@ 13'						
–					CLAY: very dark brown (10yr 2/2) to gray (10yr 6/1), trace silt and coarse grain sand, medium stiff to stiff, moist, mottled after 16-feet		Water Sample WP-FAAB-IW08-GW01 14'
	0.6 ppm @ 15'		5 (14' to 16')				
-16 –		CL					
	0.5 ppm @ 17'		50 (16' to 18')				
-18 –							

APPENDIX C

EPA METHOD 8260 PARAMETER LIST

US EPA Method 8260
PARAMETER LIST

Dichlorofluoromethane
Chloromethane
Vinyl Chloride
Bromomethane
Trichlorofluoromethane
Chloroethane
1,1-Dichloroethene
Methylene Chloride
trans-1,2-Dichloroethene
1,1-Dichloroethane
cis-1,2-Dichloroethene
Bromochloromethane
Chloroform
1,1,1-Trichloroethane
Carbon Tetrachloride
1,1-Dichloropropene
Benzene
1,2-Dichloroethane
Trichloroethene
1,2-Dichloropropane
Dibromomethane
Bromodichloromethane
cis-1,3-Dichloropropene
Toluene
trans-1,3-Dichloropropene
1,1,2-Trichloroethane
Tetrachloroethene
1,3-Dichloromethane
1,2-Dibromomethane
Chlorobenzene
1,1,1,2-Tetrachloroethane
Ethylbenzene
m & p-Xylene
o-Xylene
Styrene
Bromoform
Isopropylbenzene
Bromobenzene
1,1,2,2-Tetrachloroethane
1,2,3-Trichloropropane
n-Propylbenzene
2-Chlorotoluene
4-Chlorotoluene
1,3,4-Trimethylbenzene
tert-Butylbenzene
1,2,4-Trimethylbenzene
sec-Butylbenzene
1,3-Dichlorobenzene
p-Isopropyltoluene
1,4-Dichlorobenzene
1,2-Dichlorobenzene
n-Butylbenzene
1,2-Dibromo-3-chloropropane
1,2,4-Trichlorobenzene
Hexachlorobutadiene
Napthalene
1,2,3-Trichlorobenzene

APPENDIX D

GEO-CLEANSE® REPORT

Geo-Cleanse International, Inc.

DRAFT

Effectiveness Evaluation Report
Geo-Cleanse® Pilot Treatment Program

WRIGHT PATTERSON AIR FORCE BASE
Further Action Area B

Dayton, Ohio

Prepared for:

IT Corporation
11499 Chester Road, Suite 1100
Cincinnati, Ohio 45246

March 8, 2000

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Kenilworth, NJ 07033
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APPENDIX

1. INTRODUCTION

Geo-Cleanse International, Inc. (GCI), on behalf of the United States Air Force and IT Corporation (IT), performed a pilot test of in-situ chemical oxidation to address volatile organic compounds (VOCs) in groundwater at the Wright-Patterson Air Force Base (WPAFB) Further Action Area B (FAA-B) site in Ohio. The purposes of this Effectiveness Evaluation Report are to summarize the pilot test goals, describe the observations and results, and provide conclusions regarding the effectiveness of the Geo-Cleanse® Pilot Test Treatment Program at the FAA-B site. The following documents form the basis for historical information and contaminant characterization for the site:

- IT Corporation. *Field Activities Technical Memo. Wright-Patterson Air Force Base*. Dated September 12, 1996.
- IT Corporation. *Final Work Plan. Treatability Tests at Further Action Area A and Further Action Area B. Wright-Patterson Air Force Base. Groundwater Basewide Monitoring Program*. Dated September 23, 1999.

The remainder of this Effectiveness Evaluation Report is organized as follows:

Section 1. Introduction (this section) – Further in Section 1 is a description of the site including geologic and hydrogeologic setting, nature and extent of contamination, an overview of the Geo-Cleanse® Process and application to contaminants reported at the site, and pilot test goals.

Section 2. Treatment Program Operations and Observations – Describes field operations conducted at the site, with summaries of all analytical and field data collected prior to, during, and after field operations, hydrogen peroxide injection totals by location and date, and injector and monitoring well installation data.

Section 3. Pilot Test Treatment Program Results and Discussion – Describes and interprets the analytical results generated by the pilot test treatment program, and evaluates overall treatment performance.

Section 4. Conclusion – Presents a summary of the Geo-Cleanse® Pilot Test Treatment Program at the site, describes lessons learned by application at the site, and draws conclusions regarding overall performance and success.

Section 5, References Cited – Presents a bibliographic list of references cited in the text.

1.1 Background

IT has identified the presence of VOCs in groundwater at the WPAFB FAA-B site in Ohio. Site delineation within the treatment area, upon which the treatment program design was based, was derived from monitoring well data collected as part of previous site investigations. Additional characterization was completed immediately prior to and during injector installation at the site, which delineated a groundwater plume extending in an easterly direction (Figure 1). Analytical results indicated that VOCs were also present in unsaturated soils within the treatment area at the site (see Section 2.2 for further discussion). The compounds present were primarily the chlorinated solvent trichloroethene (TCE) and its natural degradation products cis-1,2-dichloroethene (CIS) and vinyl chloride (VC). Other compounds detected in groundwater and/or soil at the site were trans-1,2-dichloroethene (TRANS), xylenes and ethylbenzene. The maximum dissolved total VOC concentration reported within the treatment area was 8,330 μg/L detected in monitoring well MW-7 on October 4, 1999. The maximum total VOC concentration in soil was 69,600 μg/kg detected at location SB08 at a depth of 4-8 feet below grade. Dense nonaqueous phase liquids (DNAPLs) are not reported at the site and the observed concentrations are less than 1% of the pure phase water solubility, suggesting the likely absence of free product (U.S. E.P.A., 1992).

Overburden soils at the site are composed of brown clay extending to approximately 10 feet below grade overlying a sand and gravel layer of variable thickness, followed by brown clay at approximately 14 to 18 feet below grade. A second sand unit is encountered at approximately 18 to 20 feet below grade, also underlain by brown clay. Bedrock was not encountered. Depth to groundwater has historically varied from 8-12 feet below grade.

1.2 Overview of the Geo-Cleanse® Process and Application to the WPAFB FAA-B Site

The Geo-Cleanse® Process is a patented, in-situ chemical oxidation process intended to reduce organic contaminant concentrations in soil and groundwater. The Geo-Cleanse Process® is an aggressive, pressurized injection of concentrated hydrogen peroxide and ferrous iron catalyst, which together are known as Fenton's reagent and generate a hydroxyl free radical that acts as the active oxidizing agent. The basic radical-producing reaction is characterized as:

$$H_2O_2 + Fe^{+2} \rightarrow OH\cdot + OH^- + Fe^{+3}$$

where H_2O_2 is hydrogen peroxide, Fe^{+2} is ferrous iron, $OH\cdot$ is hydroxyl free radical, OH^- is hydroxyl ion, and Fe^{+3} is ferric iron. The hydroxyl free radical generated by Fenton's reagent is a powerful, non-selective oxidant. Oxidation of an organic compound by Fenton's reagent is a rapid and exothermic (heat-producing) reaction. Rate constants for reactions of hydroxyl free radical with common environmental pollutants are typically in the range of 10^7 to 10^{10} $M^{-1}s^{-1}$ (e.g., Buxton et al., 1988; Haag and Yao, 1992), and 100% mineralization is generally complete in minutes.

Site characterization data provided by IT indicate that TCE is a primary VOC found at the WPAFB FAA-B site. Fenton's reagent oxidizes chlorinated organic contaminants such as TCE to substituent carbon dioxide, water, and chloride. Leung et al. (1992) and Sato et al. (1993) have analyzed TCE destruction by Fenton's reagent, and have reported that mineralization is rapid and complete. The only significant intermediate product of Fenton's oxidation of TCE ($Cl_2C{=}CClH$) is dichloroacetic acid ($CHCl_2COOH$), which is further oxidized to formic acid ($HCOOH$) and finally to water (H_2O) and carbon dioxide (CO_2) with production of hydronium ion (H^+), and chloride ion (Cl^-) (Figure 2):

$$\begin{gathered} Cl_2C{=}CClH + OH^{\cdot} + H_2O \rightarrow CHCl_2COOH + 2H^+ + Cl^- + \\ CHCl_2COOH + 2OH^{\cdot} \rightarrow HCOOH + 2H^+ + 2Cl^- + CO_2 \\ HCOOH + 2OH^{\cdot} \rightarrow H_2O + CO_2 \end{gathered}$$

(Leung et al., 1992; Sato et al., 1992). Residual hydrogen peroxide not consumed by oxidation of organic compounds naturally decomposes to oxygen and water. Soluble ferrous iron catalyst amendments will naturally precipitate as ferric iron compounds.

1.3 Goals of the Geo-Cleanse® Pilot Treatment Program at the WPAFB FAA-B Site

Data provided by IT indicate that VOCs were concentrated in shallow groundwater within the treatment area at WPAFB FAA-B (see Section 2.2). The goal of the Geo-Cleanse® Pilot Test was to treat the contaminated plume area in the shallow sand layer to achieve VOC reduction, and to demonstrate effectiveness of the Geo-Cleanse® Process on contaminants and under the hydrogeologic conditions present at the site. Because VOCs were identified in the shallow unsaturated soils overlying the targeted pilot test treatment interval, contaminant rebound was anticipated following treatment.

2. PILOT TEST TREATMENT PROGRAM OPERATIONS AND OBSERVATIONS

2.1 Pre-Injection Organic Constituent Sampling Results

IT personnel collected soil and groundwater samples prior to injection to determine baseline VOC conditions and to further investigate the site conditions. Sixty soil samples were collected from 27 discrete locations at depths ranging from surface to 22 feet below grade. The results (Figure 3) indicate the presence of TCE and its natural degradation products (CIS and VC) in unsaturated (vadose) and saturated soils at the site. The highest concentrations were generally in the area between the concrete pad and the location of MW-3. The highest TCE concentration of 33,000 μg/kg was detected at the location of MW-7 at 4-8 feet below grade, and the highest total VOC concentration of 69,600 μg/kg (including 69,000 μg/kg of CIS) was detected at the location of SB-08 at 4-8 feet below grade. Ethylbenzene and xylenes were detected at 4 locations at depths less than 0.5 feet below grade. Full analytical results will be presented in a summary report prepared by IT.

Forty-two pre-injection groundwater samples were collected from 26 discrete locations. The four monitoring wells within or adjacent to the pilot test treatment area were sampled at least three times within three weeks of the pilot test. Grab samples of groundwater were also collected from GeoProbe® sample points at depths ranging from 8 feet to 28 feet below grade. The results (Figure 4) indicate the presence primarily of TCE, CIS and VC. The highest total VOC concentration of 624 μg/L (including 540 μg/L of CIS) was detected in SB-08 at 12-16 feet below grade. Ethylbenzene and xylenes were not detected in any of the groundwater samples. Full analytical results will be presented in a summary report prepared by IT.

2.2 Injector and Vent Well Installation

A total of eight injectors (IW-1 through IW-8) and four vent wells (V-1 through V-4) were installed at the WPAFB site from October 6- 12, 1999 at the locations indicated in Figure 1. Many of the injectors and vent wells were placed at the same location as GeoProbe® borings installed during the pre-pilot site investigation. Boreholes were drilled by hollow stem auger. Continuous split spoon samples were collected from selected injector and vent well borings to investigate the shallow stratigraphy within the treatment area and ensure optimal injector placement. The injector depths targeted the shallow sand at the site, generally between approximately 13 and 18 feet below grade. Injector and vent well construction details are summarized in Table 2. Soil boring and construction logs are included as an appendix to this report.

The injector riser, screen, and completion materials were selected and designed for resistance to the chemical reagents used, and the heat and pressure generated by the Geo-Cleanse® Process. The injectors were constructed with either 4 or 5 feet of 1¼-inch diameter, 0.010-slot stainless steel screens. The riser pipe is composed of 1¼-inch diameter Schedule 80, black steel riser pipe and couplings. The risers are enclosed in protective flush mounted well vaults. The screens were packed with filter sand and a layer of bentonite pellets was placed to seal the screened interval. The annulus was then sealed to grade with a Portland cement and bentonite grout. The injector riser has a threaded cap. The injectors are designed to accommodate the patented Geo-Cleanse® Mixing Head, which was attached directly to the riser (Figure 5). This mixing head is designed to deliver a stabilized mixture of reagents to the subsurface.

Vent wells are designed to provide controlled venting locations for offgases produced by the chemical oxidation reaction. The vent wells have much longer screened intervals, typically traversing the entire vadose zone. The vent wells were installed by IT personnel and constructed with 10 feet of 2-inch diameter Schedule 40, 0.010-slot PVC screen and 2-inch diameter Schedule 40 riser. The screens were packed with filter sand and a layer of bentonite pellets was installed to seal the screened interval. The annulus was then sealed to grade with a Portland cement and bentonite grout.

In addition to the injectors and vents, three new monitoring wells (MW-7, MW-8, and MW-9) were newly installed by IT as part of the pre-pilot site investigation to more accurately define the dissolved phase plume. All three new monitoring wells were screened within the upper sand unit with the exception of MW-7, which intersects both the upper and lower sand units within the treatment area.

2.3 Injection Operations and Observations

Field injection operations for the pilot test were conducted from October 25-29, 1999. October 25 was devoted to site preparation activities, including positioning and preparing the GCI mobile treatment unit, hydrogen peroxide tanker, and generator, establishing an exclusion zone, secondary containment installation, and preparing the safety shower and eyewash, and conducting a health and safety meeting with site personnel and base representatives. Pre-treatment activities also conducted on October 25, 1999 included pneumatic and hydraulic tests of the aquifer to determine hydrogeologic response to injection activities.

Hydrogen peroxide injection was initiated the morning of October 26, 1999. Approximately 1,088 gallons of 25% hydrogen peroxide solution and 1,242 gallons of 50% hydrogen peroxide were injected during the four days of injection (total of 1,785 gallons on a 50% basis). Injection rates ranged from 0.5 to 1.5 gallons per minute per injector for both catalyst and hydrogen peroxide. Hydrogen peroxide injection volumes by location and day are summarized in Figure 6 and Table 3. Injection volumes ranged from 73 to 289 gallons (50% concentration basis) per injector, with daily totals ranging from 314 gallons to 856 gallons. The variable injection volumes primarily reflect the ability of the aquifer to receive reagents and field indications of contaminant mass destruction (primarily carbon dioxide and oxygen levels; see Section 2.3.2). The injectors surrounding monitoring well MW-3 (IW-4, IW-5, IW-6, and IW-8; the "downgradient" injectors) received a total of 1,075 gallons of hydrogen peroxide (50% concentration basis), or approximately 60% of the hydrogen peroxide injected at the site. The injectors surrounding monitoring well MW-7 (IW-1, IW-2, IW-3, IW-7, the "upgradient" injectors) received a total of 490 gallons of hydrogen peroxide, or approximately 27% of the hydrogen peroxide injected at the site. The remaining 13% (220 gallons of hydrogen peroxide) was injected into V-4, MW-3, and MW-7.

2.3.1. Groundwater Quality Measurements

Groundwater samples were collected twice each day from monitoring and vent wells in order to determine if appropriate chemical conditions were established in the aquifer, reagents were dispersed effectively, and inert oxidation byproducts were generated (Tables 4-8). In addition to the field data, IT personnel collected pre-, during and post-treatment groundwater samples for VOC analyses. Parameters monitored to ensure that appropriate conditions were established and reagents were dispersed include pH, alkalinity, chloride, total iron and hydrogen peroxide. Fenton's reagent is most effective at mildly acidic pH ranges, and the optimal groundwater pH range for the Geo-Cleanse® Process is less than 6. High levels of dissolved carbonate and bicarbonate inhibits reduction of groundwater pH to less than 6, and carbonate is also a hydroxyl free radical trap. Accordingly, relatively low alkalinity (less than 300 mg/L) is optimal for the Geo-Cleanse® Process. Iron is a catalyst that promotes hydroxyl free radical formation (see Section 1.1), and dissolved total iron levels greater than 5 mg/L are optimal for the Geo-Cleanse® Process.

Routine groundwater sampling indicates that appropriate chemical conditions were established within the treatment zone of the aquifer. Groundwater pH within the treatment area was generally 6.0 (Table 4 and Figure 7). Notably, vent wells V-3 and V-4 exhibited no significant pH shift, indicating little or no hydraulic connection to these wells (the pH of V-4 decreased on October 29 after injection directly into that well on October 28). Alkalinity ranged from 260 to >400 mg/L (Table 5), higher than optimal but within operational ranges. Iron concentrations ranged from 0 to >10 mg/L (Table 6). Low iron concentrations result in slower hydroxyl free radical generation, which enhances hydrogen peroxide distribution and is optimal for low volatile organic concentrations. Hydrogen peroxide concentrations across the treatment area ranged from 15 to >100 mg/L during treatment (Table 7). Field analysis of groundwater was limited due to the presence of hydrogen peroxide in samples.

Chloride is produced as a byproduct of chlorinated solvent oxidation (see Section 1.2). The field data indicated relatively low concentrations (<40 mg/L) that remained unchanged over the course of treatment (Table 8). This is consistent with the chlorinated organic compound levels observed at the site. For example, TCE is approximately 81% chloride by mass. Thus if the maximum concentration observed is 624 μg/L (SB-08; Figure 4), the corresponding maximum chloride increase (representing 100% contaminant destruction) is approximately 0.5 mg/L. The resolution of the field test is ±5 mg/L and, therefore, not sufficiently sensitive to detect the anticipated small chloride signal.

Photoionization detector (PID) measurements of groundwater headspace samples are utilized as a semi-quantitative measure of dissolved VOC concentrations. The PID measures volatile organic compounds in the gas headspace trapped above a water sample in a sealed jar. The concentration of volatile organic compounds in the gas headspace, in turn, is proportional to the concentration dissolved in groundwater, as dictated by Henry's Law. Thus the PID readings provide rapid field measures of VOC concentrations in groundwater. The sensitivity of the PID is approximately 1 part per million. The VOC concentrations in groundwater at the WPAFB site were relatively low (<1.0 mg/L in the treatment area). Therefore, as expected, headspace concentrations at the WPAFB site were also relatively low (maximum of 4.1 ppm) and did not significantly affect the injection plan (Table 9).

2.3.2. Offgas Composition Measurements

Bubbling was observed in water within the wells as a result of offgas production from the oxidation process. Offgases liberated via the monitoring wells, injectors, and vent wells were routinely monitored for carbon dioxide and oxygen concentration (Tables 10-11). The concentration of these gases provides a measure of VOC oxidation and treatment progress. Carbon dioxide is produced as a product of

VOC oxidation (see Section 1.2), and by acidic reaction with carbonates. In the absence of organic compounds (reflecting progressive destruction of the VOCs), reaction of hydroxyl free radicals with hydrogen peroxide or other radicals generates oxygen. Thus in general, over the course of a Geo-Cleanse® injection, carbon dioxide levels reach maxima (~10-15% at sites impacted by chlorinated VOCs) in the first few days of injection and decrease over the course of treatment, while oxygen levels progressively increase and PID readings progressively decrease throughout the treatment.

Carbon dioxide is produced by oxidation of organic compounds and by reaction of the acidic catalyst with carbonate dissolved in groundwater or present in the soil matrix. In order to distinguish between these components, carbon dioxide concentrations were measured while injecting only catalyst on October 25. Carbon dioxide was detected during catalyst injection at three out of eight points monitored (Table 10 and Figure 8). The maximum carbon dioxide concentration measured on October 25 was 5.9% (from MW-3), and the average of all of the measurements was 0.8%. The "background" is taken as the site average for each of the wells, which was found to be 1.1%. The maximum carbon dioxide concentration observed during hydrogen peroxide injection was 12.1% in V-3 on October 27. Overall, the highest average carbon dioxide concentrations were detected in V-4 (Figure 8). V-4 also exhibited the expected pattern of a broad increase and subsequent decrease, indicating destruction of organic contaminants in the treatment area (Figure 9). In general most of the measurements were less than 6% (Table 10), consistent with observations from other sites impacted by chlorinated VOCs.

Oxygen levels were initially extremely low, with zero (nondetectable, <0.1%) readings observed in several of the wells in the first two days of injection (Table 11). This is interpreted to reflect the impact of a hydrogen injection test conducted at the site by IT prior to the Geo-Cleanse® Pilot Treatment. No zero readings were detected after the second day of injection. The offgas oxygen concentration exhibited the expected trend of progressive increase over the course of the treatment (Figure 10). Overall, the site-average oxygen concentration increased from 13% to 55.6% over the course of treatment. The maximum observed during the treatment was 79.5% in V-1 on October 28, near the end of the pilot test. As with groundwater pH, very little effect was observed in V-3, indicating little if any pneumatic connection with that vent well. In contrast to groundwater pH, however, V-4 did exhibit pneumatic connection with the injection and a progressive increase in oxygen concentration during treatment.

2.3.3. Radius of Influence

Data to evaluate the effective radius of influence include observations of mounding groundwater, gas bubbling, or pressurization of monitoring wells, distribution of reagents and reaction products, and post treatment organic constituent sampling of soil and groundwater. During the injection, the most direct evidence of the radius of influence is detection of hydrogen peroxide in monitoring wells adjacent to active injectors. On the first day of hydrogen peroxide injection (October 25), hydrogen peroxide was detected in vent well V-2 while injecting into IW-6 (Tables 3 and 7), indicating a minimum radius of influence of at least 10 feet (the approximate distance between V-1 and IW-6). On the second day of injection (October 25), hydrogen peroxide was detected in V-1, V-2, MW-3, and MW-7 while injecting into IW-3, IW-4, IW-6, and IW-7, a distance of approximately 12 feet (from IW-4 to MW-3). These data indicate that a minimum radius of influence of 12 feet was achieved. Hydrogen peroxide was not detected in V-4 until after injection directly into that well on October 28. Assuming that V-4 was not hydraulically isolated from the aquifer (possibly due to "smearing" of the boring wall during drilling), then the maximum radius of influence from injector IW-3 was less than approximately 10 feet. Vent well V-3 was hydraulically and pneumatically isolated from the treatment area, with no decrease in groundwater pH or significant offgas carbon dioxide or oxygen trends. V-3 is located approximately 23 feet from IW-4, providing an upper bound to the radius of influence.

2.3.4. Organic Constituent Sampling During and Post-Treatment

IT personnel collected daily groundwater samples during treatment from monitoring wells MW-3 and MW-7 for VOC analysis. Samples were analyzed at an on-site mobile laboratory. Results were used to monitor the progress of the treatment program and adjust rates and volumes to reflect areas requiring further treatment. Results from both MW-3 and MW-7 were variable over the course of treatment. IT personnel collected groundwater samples from monitoring wells within the treatment area on November 1, November 15, and December 15, 1999 to monitor long-term treatment effects. The VOC results are discussed in Section 3.1. In addition to the chlorinated solvents detected prior to treatment, acetone and 2-butanone (methyl ethyl ketone, or MEK) were detected on October 29 and in the post-treatment sampling rounds of MW-3 and MW-7. Possible causes for the appearance of acetone and MEK are further discussed in Section 3.2.

3. TREATMENT PROGRAM RESULTS

3.1. Groundwater VOC Results

Pre-injection VOC concentrations within the central plume area ranged from 41.6 to 624 µg/L of total VOCs (SB-04 and SB-08, respectively). Four locations provide comparison of pre- and post-treatment VOC results: permanent monitoring wells MW-3 and MW-7, comparison of groundwater grab sample results for SB-02 with post-injection results from IW-7, and comparison of groundwater grab sample results for SB-10 with post-injection results from IW-1. The groundwater analytical results are summarized in Table 1 and Figure 11.

Overall, the analytical results are extremely variable and suggest little net impact on groundwater VOC concentrations (Figure 11). Chlorinated VOC levels (which excludes acetone and MEK; see Section 3.2) in MW-7 initially decreased from 202.9 μg/L on October 22 to 109.6 μg/L on November 1, then increased to 1,435.5 μg/L on November 15 and 503.7 μg/L on December 15. Chlorinated VOC levels in MW-3 initially decreased from 87.3 μg/L on October 22 to 78.8 μg/L on November 1, then decreased further to 75.4 μg/L on November 15 and increased to 89.3 μg/L on December 15. Results from the SB-2/IW-7 location indicated an increase from 61.8 to 104.5 μg/L, while results from the SB-10/IW-1 location indicates a decrease from 644 μg/L to 183.1 μg/L.

A notable trend observed in the data is the relative concentrations of TCE and its natural degradation products over the course of injection. Prior to injection, TCE concentrations were generally lower than CIS, TRANS and VC concentrations. In contrast, during and immediately after the treatment TCE concentrations were higher than the breakdown products, and the relative concentrations returned to pre-injection levels over the two-month period following injection. This is best expressed in a plot of the ratio of the concentration of TCE divided by the sum of the concentrations of CIS, TRANS and VC with time (Figure 12). The pre-injection ratio of TCE to the sum of CIS, TRANS and VC is less than 0.2 (average of 0.07) in both MW-3 and MW-7 for three groundwater sampling rounds. During injection, the ratio ranges from 0.13 to 1.47 (with an average of 0.56). Following injection, the ratios are greater than 0.6 and progressively decrease to pre-injection ratios over two months. Thus although the overall chlorinated VOC concentrations do not exhibit an interpretable trend, the individual compounds present show significant changes over the course of the treatment. The VC, CIS and TRANS decrease significantly during and immediately following injection while TCE increases, and subsequent to treatment the TCE decreases while the degradation products recover. Based upon this trend, it appears that the chlorinated VOCs in groundwater during and immediately following treatment represent an influx of new contamination, most likely from the overlying vadose zone. The overlying vadose zone at the site is known to have chlorinated VOC contamination (see Section 2.1) which does not have VC, with contamination immediately above the water table. Because the injection process causes mounding of warm groundwater into the vadose zone, the soil contaminants may be mobilized into the groundwater as a result of the enhanced circulation.

specially designed injectors and four vent wells were installed in a vertical and horizontal array encompassing the targeted source area of the plume. A total of 1,088 gallons of 25% hydrogen peroxide solution and 1,241 gallons of 50% hydrogen peroxide were injected over the course of a five-day pilot test from October 26 to October 29, 1999.

Chlorinated VOC results appear ambiguous if only the total chlorinated VOC concentrations are considered. However, the relative contribution of TCE to the sum of its degradation products (CIS, TRANS, and VC) changes dramatically as a result of the pilot treatment. Prior to injection, the degradation products were present at relatively greater concentrations than during or after the treatment. Six weeks after treatment, the degradation products have recovered. This most likely reflects destruction of the groundwater chlorinated VOCs with introduction of new chlorinated VOCs (primarily TCE) from the overlying vadose zone. Mounding of groundwater with elevated temperature as a result of the pilot test would flush contaminants from the overlying vadose zone. The overlying vadose zone is known to be contaminated.

Acetone and MEK were detected in groundwater after the injection. The source of the acetone and MEK is not clear. Neither compound is produced as an intermediate product of Fenton's reagent oxidation of TCE or the other known contaminants at the site, and a source could not be identified. Neither acetone not MEK are susceptible to destruction by Fenton's reagent. Regardless of the source, both are readily biodegraded by natural processes. Forty-five days after injection, acetone and MEK were not detected at the site.

Based upon the results of the pilot test, it appears as though the Geo-Cleanse® Process may provide an effective remedial alternative for the site. However, groundwater treatment at the site (by any technology) will only be effective if the overlying vadose zone soils are remediated prior to implementing the Geo-Cleanse® Process.

5. REFERENCES

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Table 1. Pre- and Post-Treatment Groundwater Volatile Organic Compound Results

MW-3 Analyte (µg/L)	Pre-Treatment 10/20/99	Post-Treatment 11/1/99	Post-Treatment 11/15/99	Post-Treatment 12/15/99
Trichloroethene	<1	31.8	13.5	4.4
Vinyl Chloride	82	<2	24.2	24.2
Total Volatile Organics	87.3	1,808.8	195.4	89.3
Acetone	NA	1,730	120	<20
2-Butanone (MEK)	NA	<62	<12.5	<12.5
MW-7 Analyte (µg/L)	Pre-Treatment 10/22/99	Post-Treatment 11/1/99	Post-Treatment 11/15/99	Post-Treatment 12/15/99
Trichloroethene	7.9	54.8	630	61.7
Vinyl Chloride	25	<2	4.9	5.4
Total Volatile Organics	202.9	1,217.6	1,694.5	503
Acetone	NA	986	259	<20
2-Butanone (MEK)	NA	122	<12.5	<12.5

SB-2/IW-7 Analyte (µg/L)	Pre-Treatment 9/28/99	Post-Treatment 11/1/99	Post-Treatment 12/15/99
Trichloroethene	<1	15	6.8
Vinyl Chloride	58	<5	71.9
Total Volatile Organics	61.8	786.5	354.4
Acetone	NA	620	28.9
2-Butanone (MEK)	NA	62	<12.5
SB-10/IW-1 Analyte (µg/L)	Pre-Treatment 9/30/99	Pre-Treatment 10/12/99	Post-Treatment 12/15/99
Trichloroethene	55.0	11.0	3
Vinyl Chloride	49	<5	12.9
Total Volatile Organics	644	2,440.8	183.1
Acetone	NA	1,820	<20
2-Butanone (MEK)	NA	526	<12.5

Notes:
Only selected compounds shown.
NA = Not Analyzed

Table 2. Injector and Vent Well Construction Summary

Injector	Borehole Depth (ft)	Screened Interval (ft)
IW-1	18.2	13.2 - 18.2
IW-2	18.5	13.7 - 18.5
IW-3	18.0	14 - 18
IW-4	14.2	10.2 - 14.2
IW-5	16.0	11-16
IW-6	17.5	12.5 - 17.5
IW-7	17.0	13 - 17
IW-8	18.0	13 - 18
V-1	18.0	8-18
V-2	18.0	8-18
V-3	18.0	8-18
V-4	18.0	8-18

Table 3. Hydrogen Peroxide Injection Volumes by Location and Date

	25% H_2O_2		50% H_2O_2		Total (gal
Station/Date	10/26/99	10/27/99	10/28/99	10/29/99	50% basis)
IW-1	27	0	155	0	**169**
IW-2	0	34	25	101	**143**
IW-3	50	161	0	0	**105**
IW-4	78	78	206	0	**284**
IW-5	0	78	220	0	**259**
IW-6	85	179	56	101	**289**
IW-7	75	71	0	0	**73**
IW-8	0	173	56	101	**244**
V-4	0	0	21	0	**21**
MW-3	0	0	0	82	**82**
MW-7	0	0	117	0	**117**
Daily Total (gal)	**314**	**773**	**856**	**386**	**1,785**
Total to Date (gal)	**314**	**1,088**	**1,944**	**2,329**	

Table 4. Groundwater pH Measurements

(standard units)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/6/99	1545	6.5	7.0	—	—	—	—
10/25/99	1445	7.2	7.1	7.0	6.9	7.1	7.2
	1800	6.5	—	6.8	—	—	—
10/26/99	0910	6.6	7.1	7.1	6.9	7.0	7.0
	1530	6.0	6.0	6.0	6.5	7.0	7.1
10/27/99	0830	6.0	6.0	6.0	6.0	7.1	7.1
	1500	6.0	6.0	6.0	6.0	7.0	7.0
10/28/99	0845	6.0	6.0	6.0	6.0	7.0	7.1
	1545	7.0	—	6.0	6.6	7.0	7.0
10/29/99	0830	6.0	6.0	6.0	6.0	7.2	6.0

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 5. Groundwater Alkalinity Measurements

(mg/L as $CaCO_3$)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/6/99	1545	320	280	—	—	—	—
10/25/99	1445	320	280	340	400	400	260
10/26/99	0910	300	260	380	400	>400	280
	1530	—	—	—	—	>400	300
10/27/99	0830	—	—	—	—	>400	300
	1500	—	—	—	—	>400	320
10/28/99	0845	—	—	—	—	>400	340
	1545	—	—	—	—	>400	—
10/29/99	0830	—	—	—	—	>400	—

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 6. Groundwater Total Iron Measurements

(mg/L)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/6/99	1545	2.8	4.8	-----	-----	-----	-----
10/25/99	1445	3.5	>10	1.9	1.0	1.0	2.5
10/26/99	0910	2.7	5.5	2.8	1.0	1.0	1.5
	1530	-----	-----	-----	-----	1.5	5.0
10/27/99	0830	-----	-----	-----	-----	1.5	3.0
	1500	-----	-----	-----	-----	1.5	3.5
10/28/99	0845	-----	-----	-----	-----	1.0	1.5
	1545	>10	-----	4.4	8.8	1.0	-----
10/29/99	0830	-----	-----	-----	-----	1.0	-----

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 7. Groundwater Hydrogen Peroxide Measurements

(mg/L)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/25/99	1445	0	0	0	0	0	0
	1414	-----	-----	-----	>100	-----	-----
10/26/99	1030	15		>30			
	1530	30	50	>100	>100	0	0
10/27/99	0830	30	30	30	30	0	0
	1500	30	30	50	30	0	0
	1815	-----	-----	-----	-----	0	0
10/28/99	0845	10	10	10	30	0	0
	1545	30	-----	30	30	0	50
10/29/99	0830	30	50	50	50	0	50

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 8. Groundwater Chloride Measurements

(mg/L)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/6/99	1545	40	40	-----	-----	-----	-----
10/25/99	1445	20	15	20	55	20	15
10/26/99	0910	35	20	20	30	20	15
	1530	-----	-----	-----	-----	25	20
10/27/99	0830	-----	-----	-----	-----	20	20
	1500	-----	-----	-----	-----	25	25
10/28/99	0845	-----	-----	-----	-----	25	25
	1545	-----	-----	-----	-----	25	-----
10/29/99	0830	-----	-----	-----	-----	25	-----

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 9. Groundwater Headspace Photoionization Detector Measurements

(parts per million by volume)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4
10/25/99	1445	0.0	0.0	0.0	9.0	0.0	0.0
10/26/99	0910	0.8	1.0	0.0	0.0	0.5	0.0
	1530	0.0	0.5	0.0	0.0	0.0	0.0
10/27/99	0830	0.0	2.6	0.0	0.0	0.0	0.0
	1500	0.0	4.1	0.0	0.0	0.0	2.3
10/28/99	0845	0.0	2.6	0.0	0.0	0.0	4.1
10/29/99	0830	0.0	0.0	0.0	0.0	0.0	0.0

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 10. Offgas Carbon Dioxide Measurements

(percent by volume)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4	IW-4	IW-5	IW-6	IW-8
10/25/99	1445	0.0	—	0.2	1.1	0.0	—	0.0	0.0	0.0	0.0
	1735	5.9	—	0.4	—	—	—	—	—	—	—
10/26/99	0830	2.0	0.0	1.6	0.7	0.0	0.8				
	1120	3.4	0.0	5.1	3.2	0.0	3.0				
	1240	2.7	0.0	2.0	2.9	0.0	2.8				
	1414	2.8	4.6	0.9	4.5	0.0	5.6				
	1610	3.1	0.8	0.3	4.7	0.0	7.2				
10/27/99	0950	6.6	0.1	0.1	1.0	12.1	0.1				
	1130	4.7	0.0	1.2	3.4	0.0	10.0				
	1400	5.7	4.1	4.3	4.9	0.0	8.7				
	1615	5.6	4.9	1.7	4.7	0.0	8.0				
	1810	3.0	2.1	4.4	5.0	0.0	5.7				
10/28/99	0945	7.5	0.7	0.4	7.3	0.0	—				
	1145	1.1	11.6	2.6	4.7	0.0	8.6				
	1345	1.9	—	1.9	3.8	0.0	—				
	1600	2.4	—	2.0	3.4	2.4	4.9				
10/29/99	0915	—	0.4	2.7	5.9	0.0	6.8				
	1045	—	0.4	1.2	5.0	0.0	5.1				

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

Table 11. Offgas Oxygen Measurements

(percent by volume)

Date	Time	MW-3	MW-7	V-1	V-2	V-3	V-4	IW-4	IW-5	IW-6	IW-8
10/25/99	1445	19.8	—	17.4	5.1	19.7	—	19.3	3.5	19.6	8.7
	1735	0.0*	—	17.4	—	—	—	—	—	—	—
10/26/99	0830	11.7	17.3	12.4	15.7	18.4	9.4				
	1120	72.8	19.1	28.7	0.0	19.0	0.0				
	1240	72.8	18.8	32.3	0.0	0.0	0.0				
	1414	74.5	72.7	29.3	67.2	20.1	52.3				
	1610	72.3	25.2	15.9	56.9	0.0	62.0				
10/27/99	0950	53.3	20.0	19.7	15.3	—	2.5				
	1130	56.1	20.2	21.6	35.1	19.5	63.3				
	1400	59.3	74.0	64.2	48.3	19.8	71.9				
	1615	68.3	75.1	28.0	71.5	20.0	72.1				
	1810	35.0	41.5	75.7	76.7	21.4	75.0				
10/28/99	0945	70.6	21.5	14.6	43.7	20.0	—				
	1145	27.0	66.6	57.0	75.7	20.0	71.9				
	1345	61.3	—	61.3	79.1	21.7	—				
	1600	79.4	—	79.5	77.7	20.9	44.6				
10/29/99	0915	—	37.5	78.2	75.0	20.2	74.8				
	1045	—	75.4	26.5	71.4	19.8	76.8				

Note: A blank space indicates that the location did not exist at the time of sampling, or was not sampled due to presence of hydrogen peroxide, elevated pressure, or groundwater mounding.

** A hydrogen injection pilot study was conducted prior to the initiation of the chemical oxidation program*

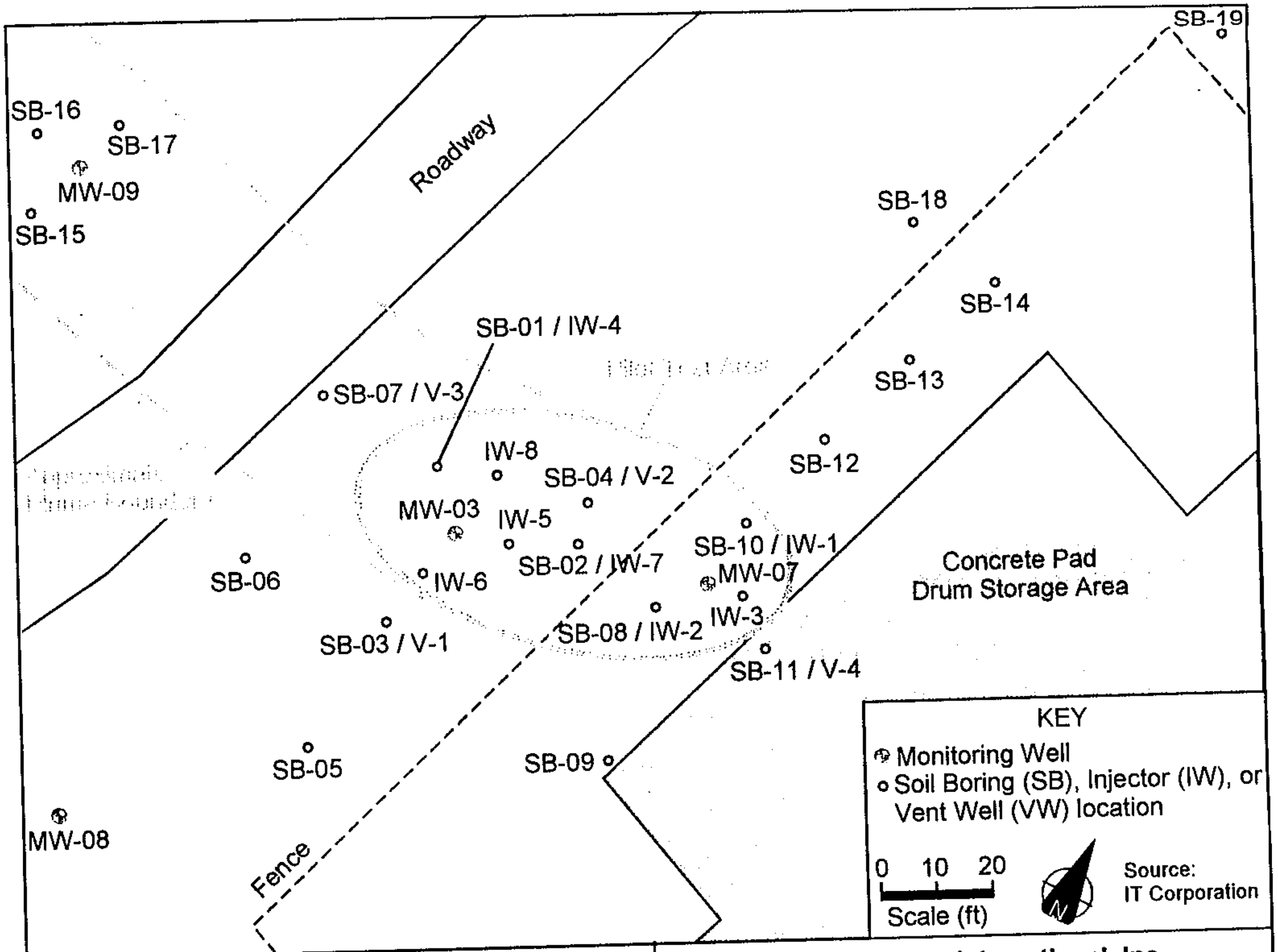
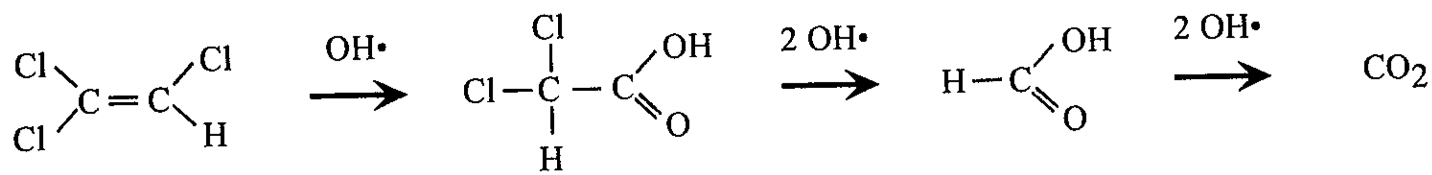


FIGURE 1. Site Layout Map

Geo-Cleanse International, Inc.
4 Mark Road, Suite C
Kenilworth, NJ 07033

Trichloroethene Oxidation Pathway



Trichloroethene | Dichloroacetic Acid | Formic Acid | Carbon Dioxide

References: Leung et al. 1992; Sato et al. 1993

FIGURE 2. Fenton's Reagent Oxidation Pathway for Trichloroethene (TCE)

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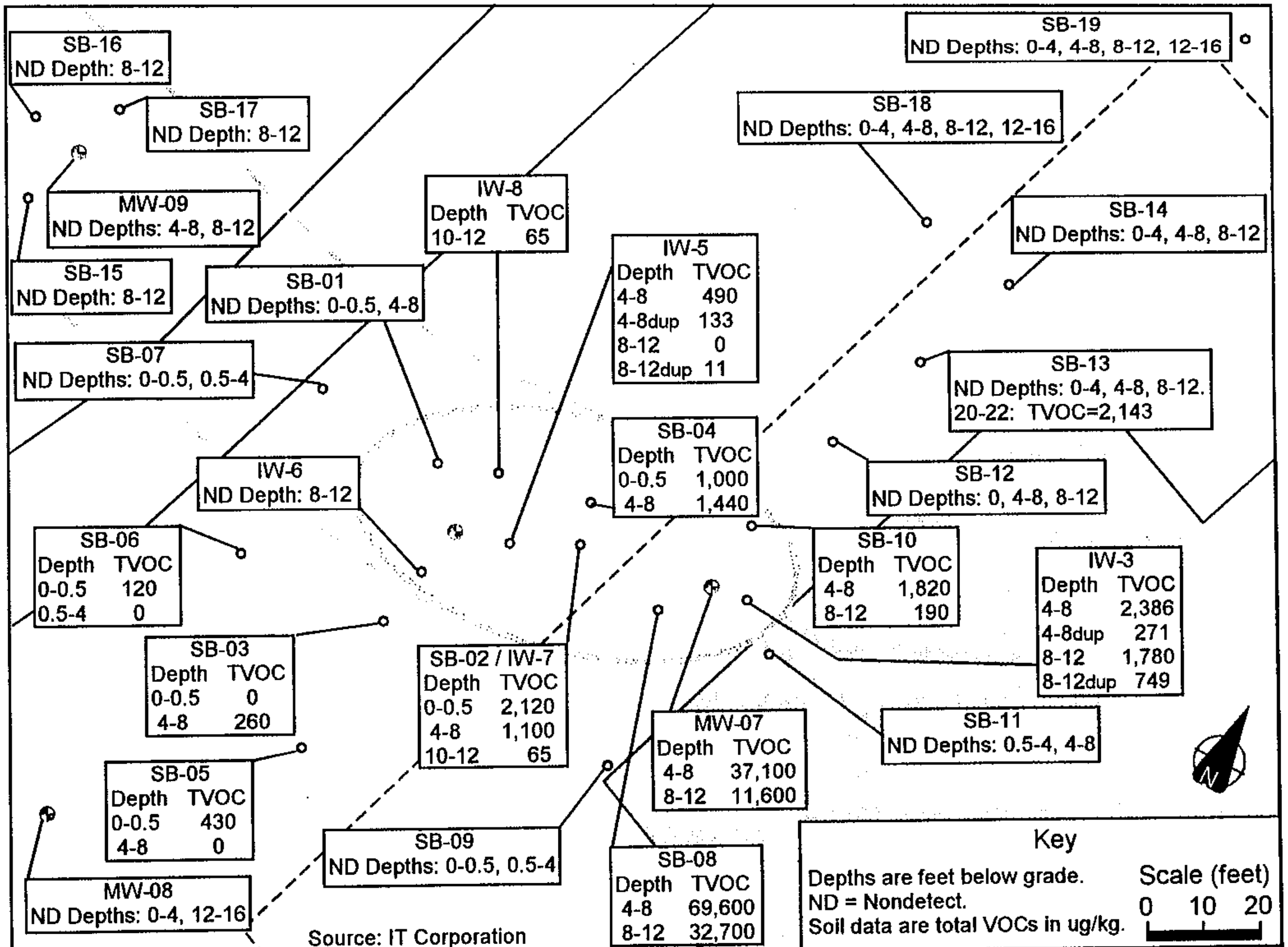

FIGURE 3. Pre-Injection Soil Analytical Results

Source: IT Corporation

Geo-Cleanse International, Inc.
4 Mark Road, Suite C
Kenilworth, NJ 07033

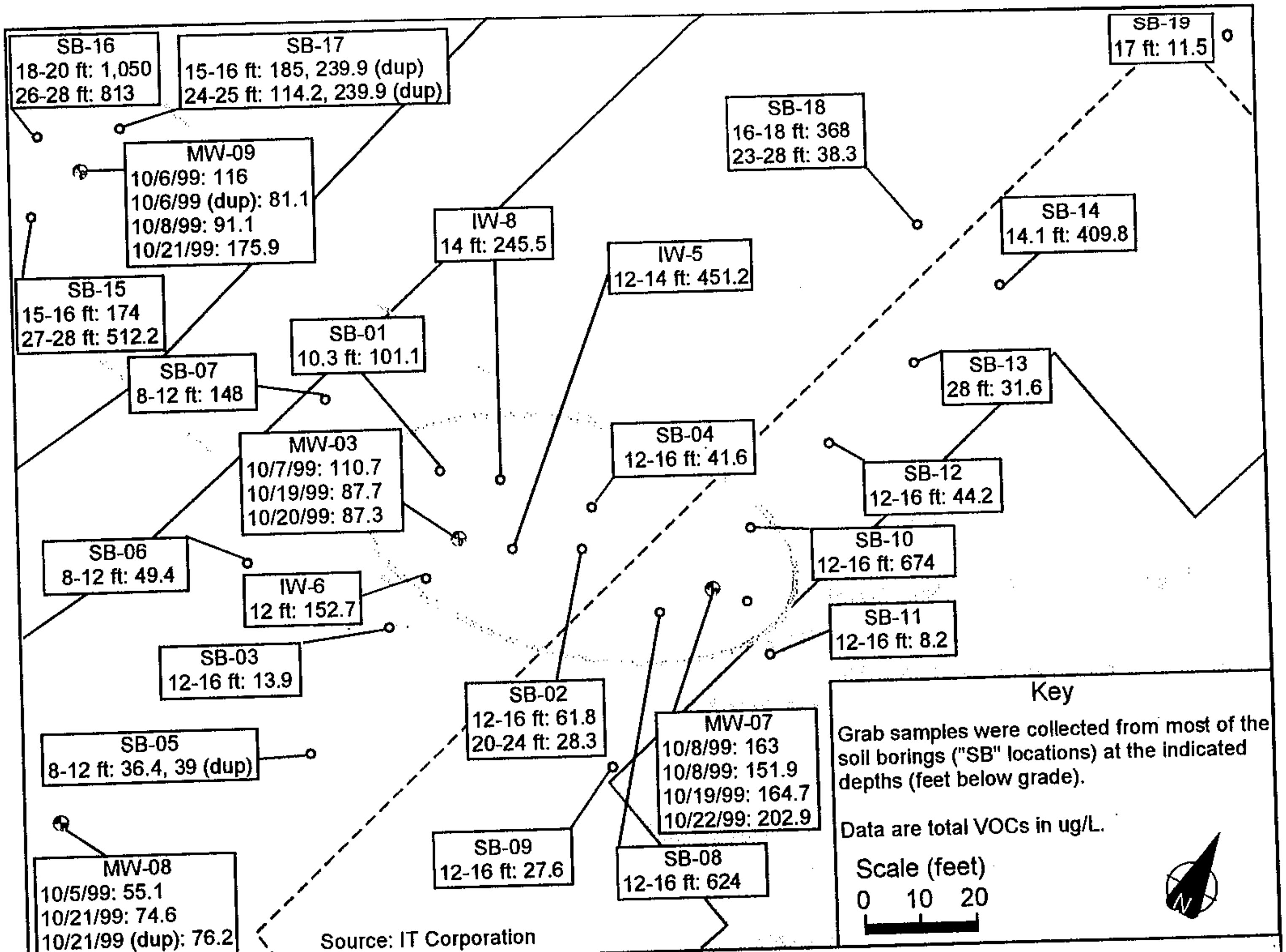

FIGURE 4. Pre-Injection Groundwater Analytical Results

Source: IT Corporation

Geo-Cleanse International, Inc.
4 Mark Road, Suite C
Kenilworth, NJ 07033

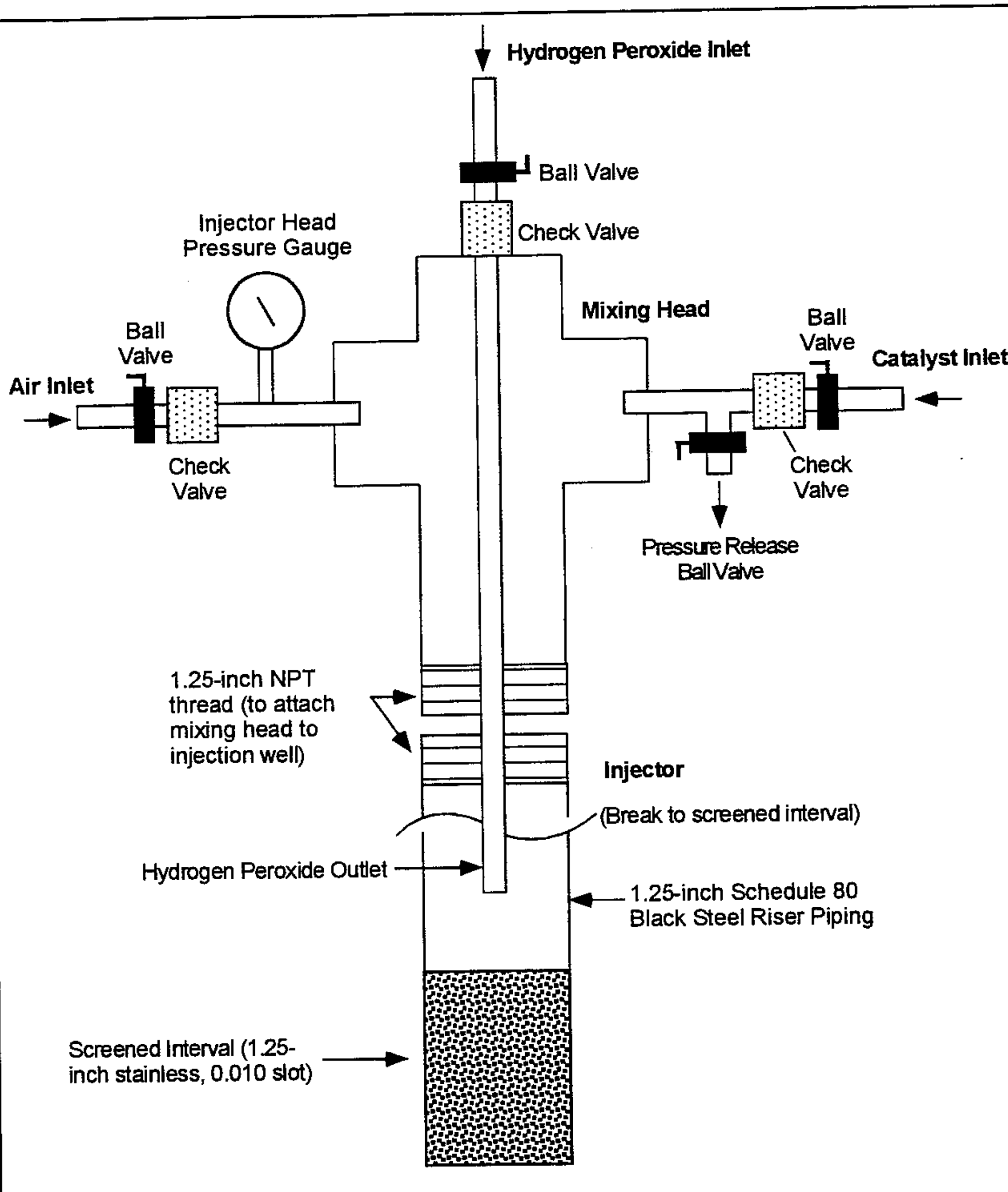

FIGURE 5. Geo-Cleanse® Patented Injector and Mixing Head Design Schematic (U.S. Patents 5,525,008 and 5,611,642)

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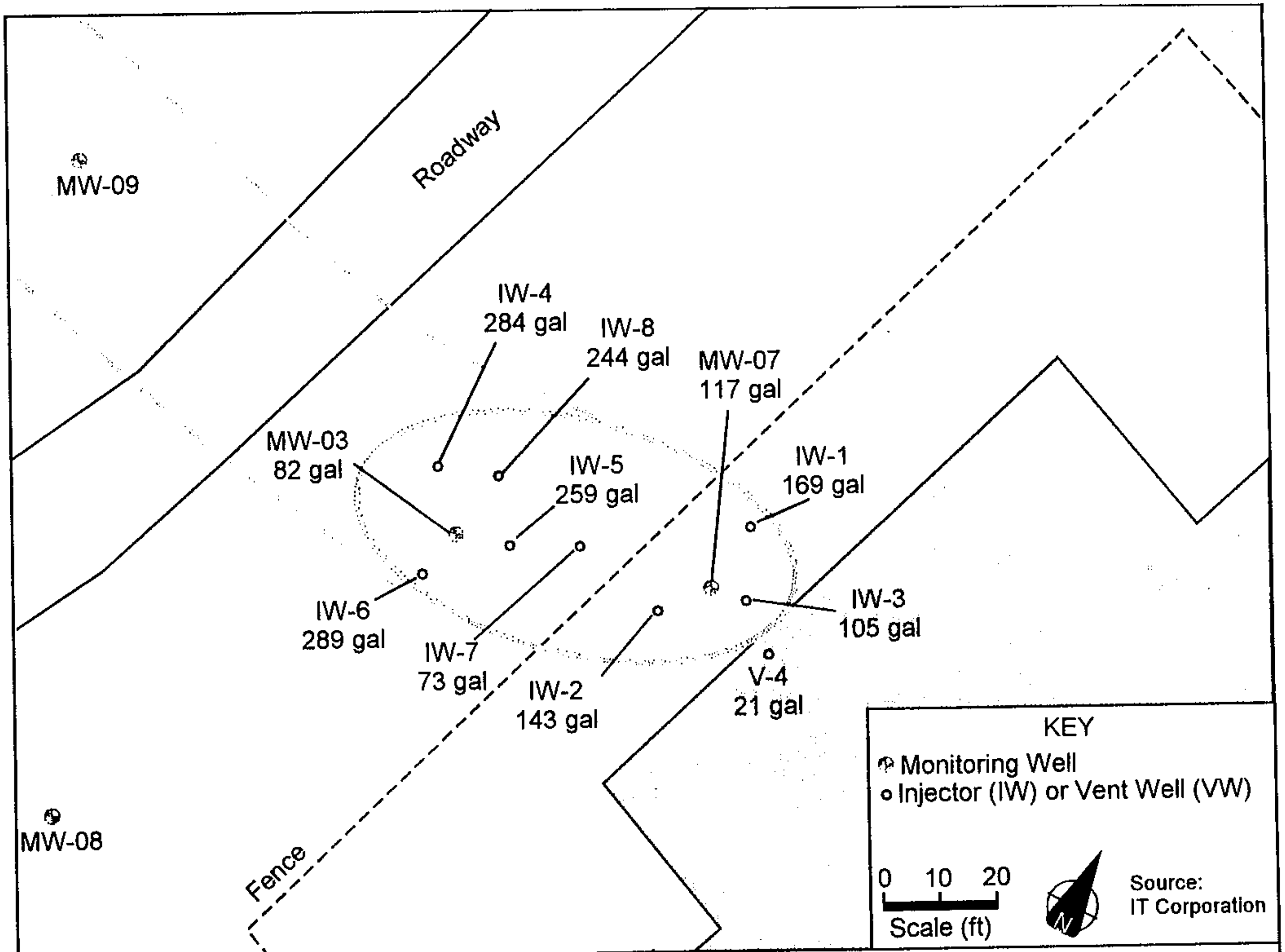

FIGURE 6. Hydrogen Peroxide Injection Totals by Location

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Figure 7. Groundwater pH Measurements

Daily Averages by Location

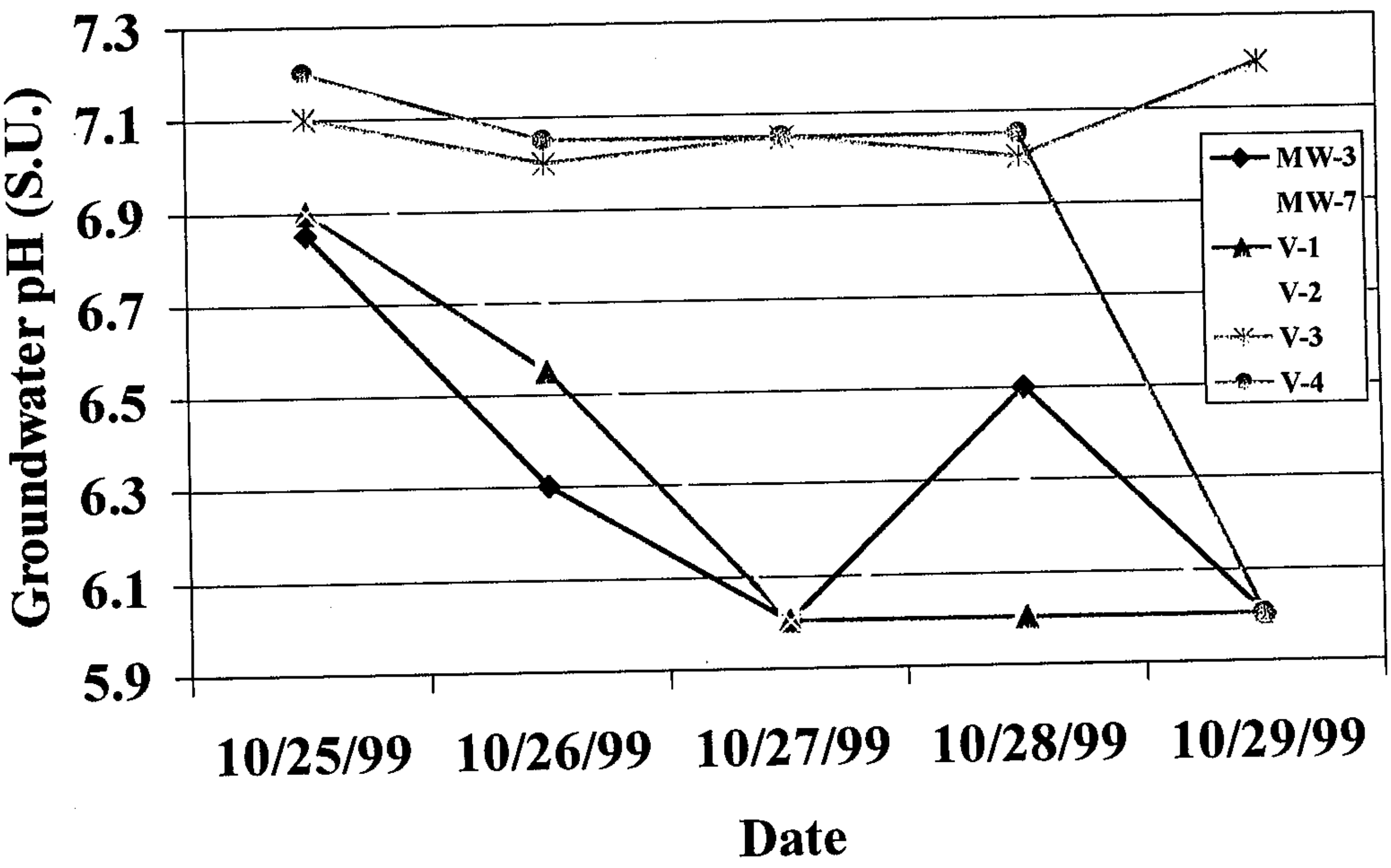


Figure 8. Offgas Carbon Dioxide Measurements

Daily Averages by Location

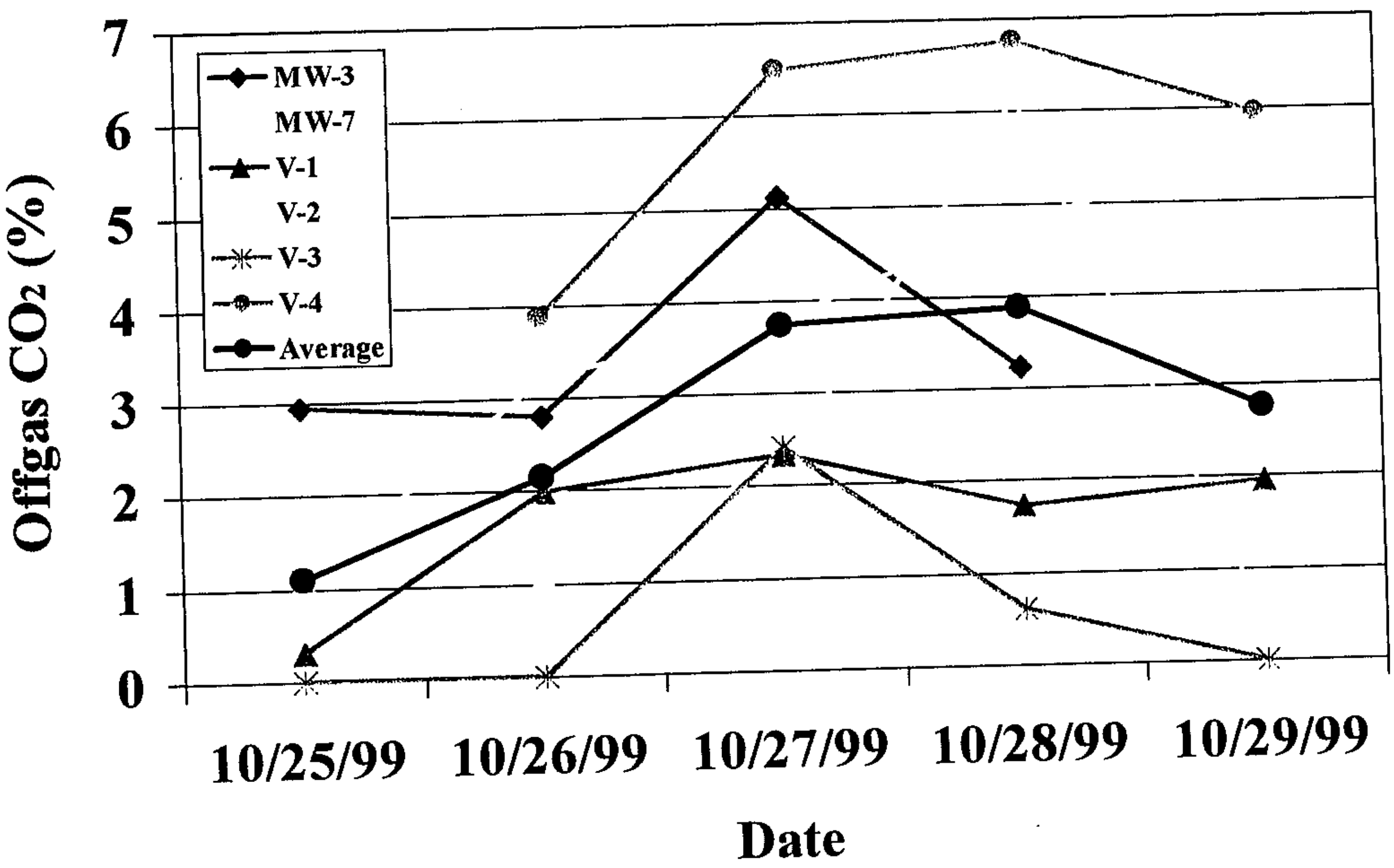


Figure 9. V-4 Offgas Carbon Dioxide Measurements

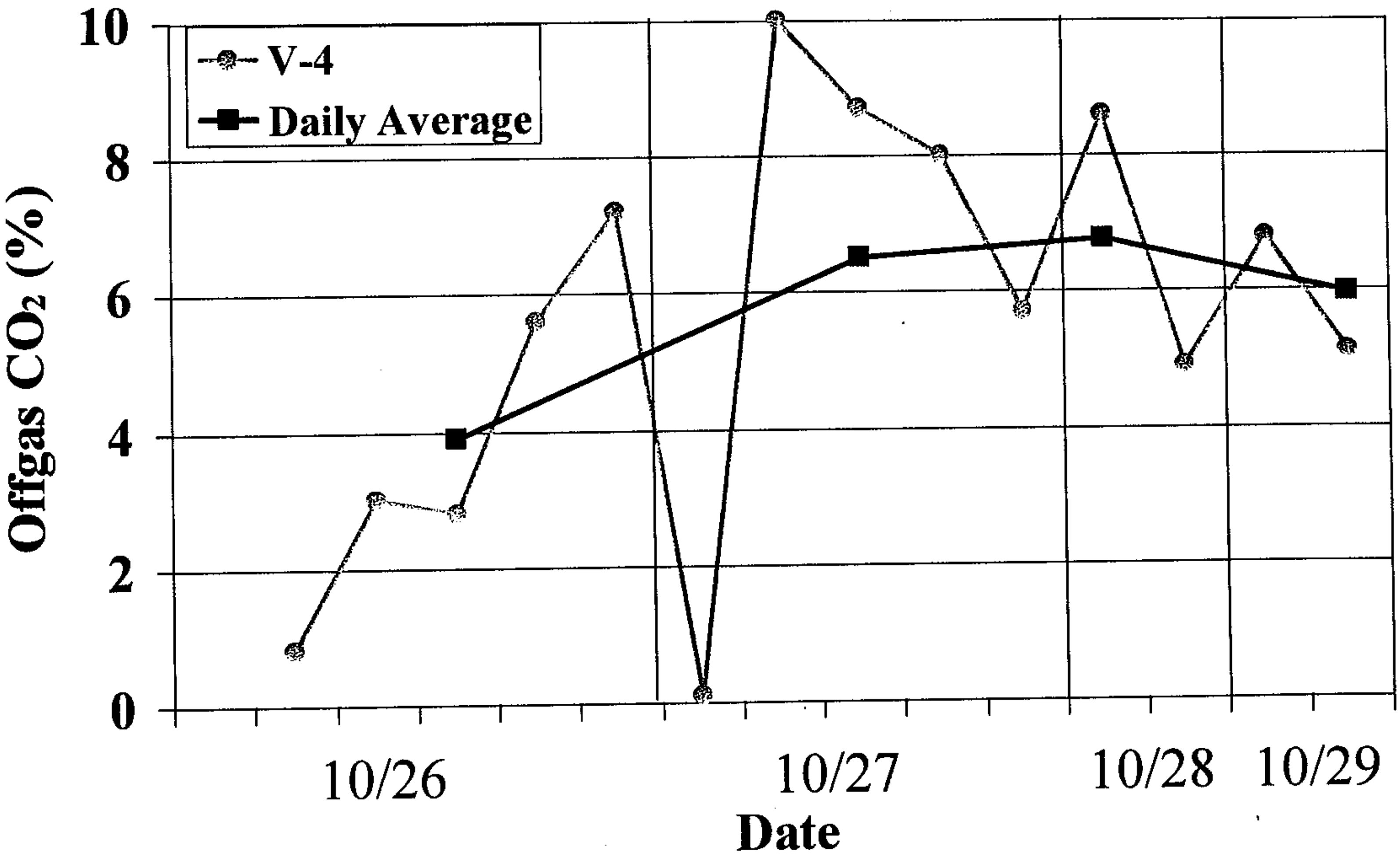


Figure 10. Offgas Oxygen Measurements

Daily Averages by Location

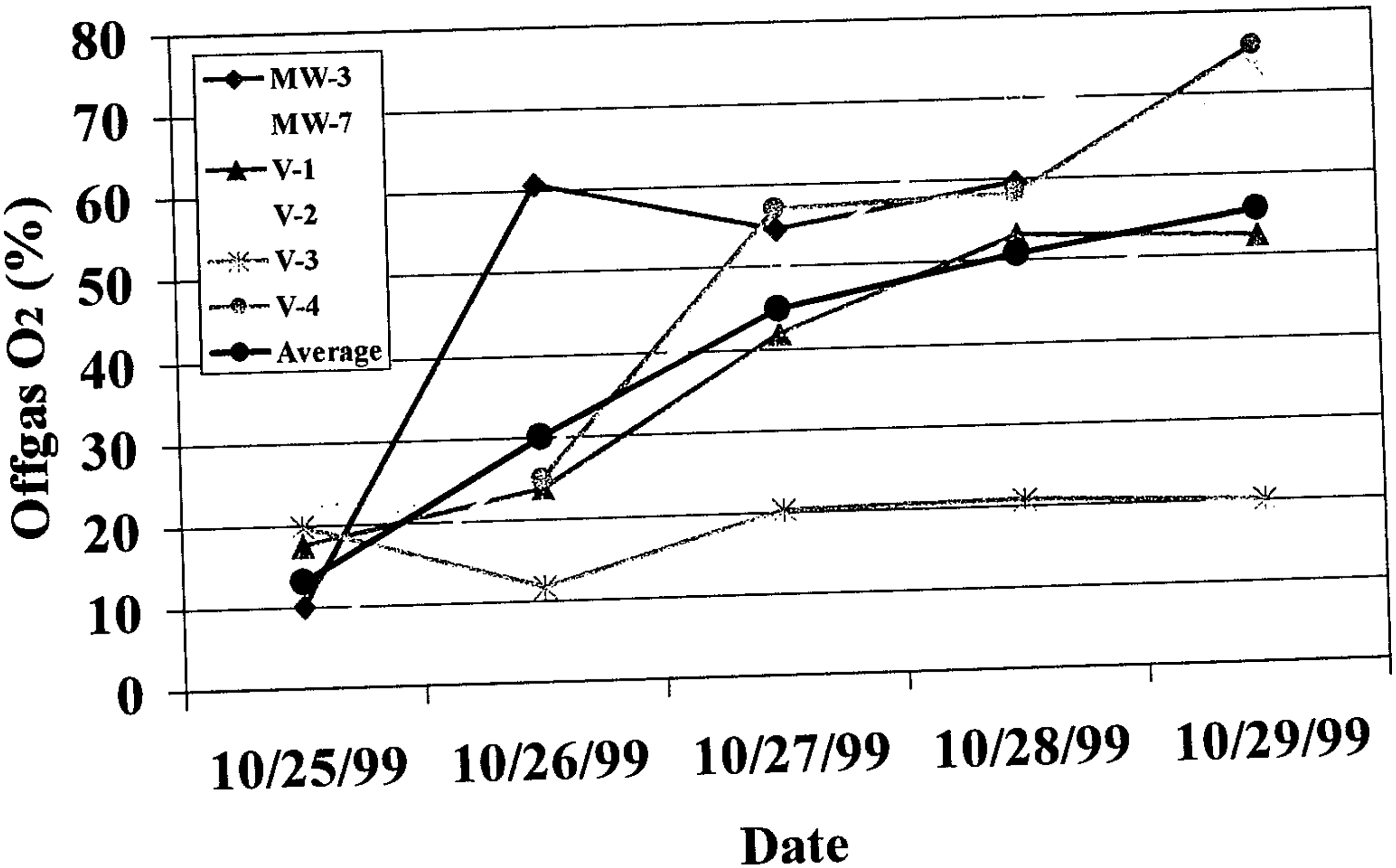


Figure 11. Overall Groundwater Chlorinated VOC Results

(Excludes Acetone and MEK)

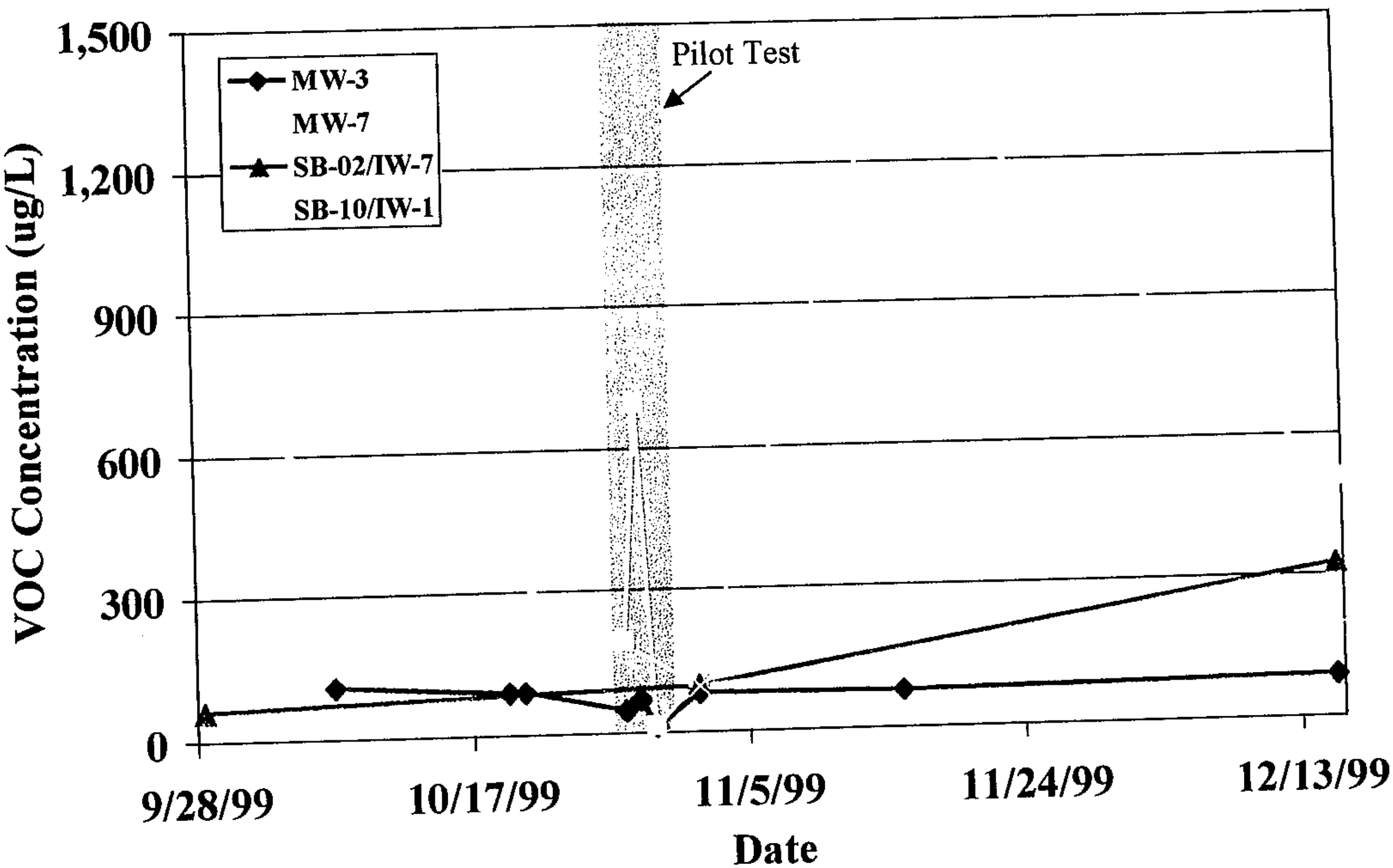
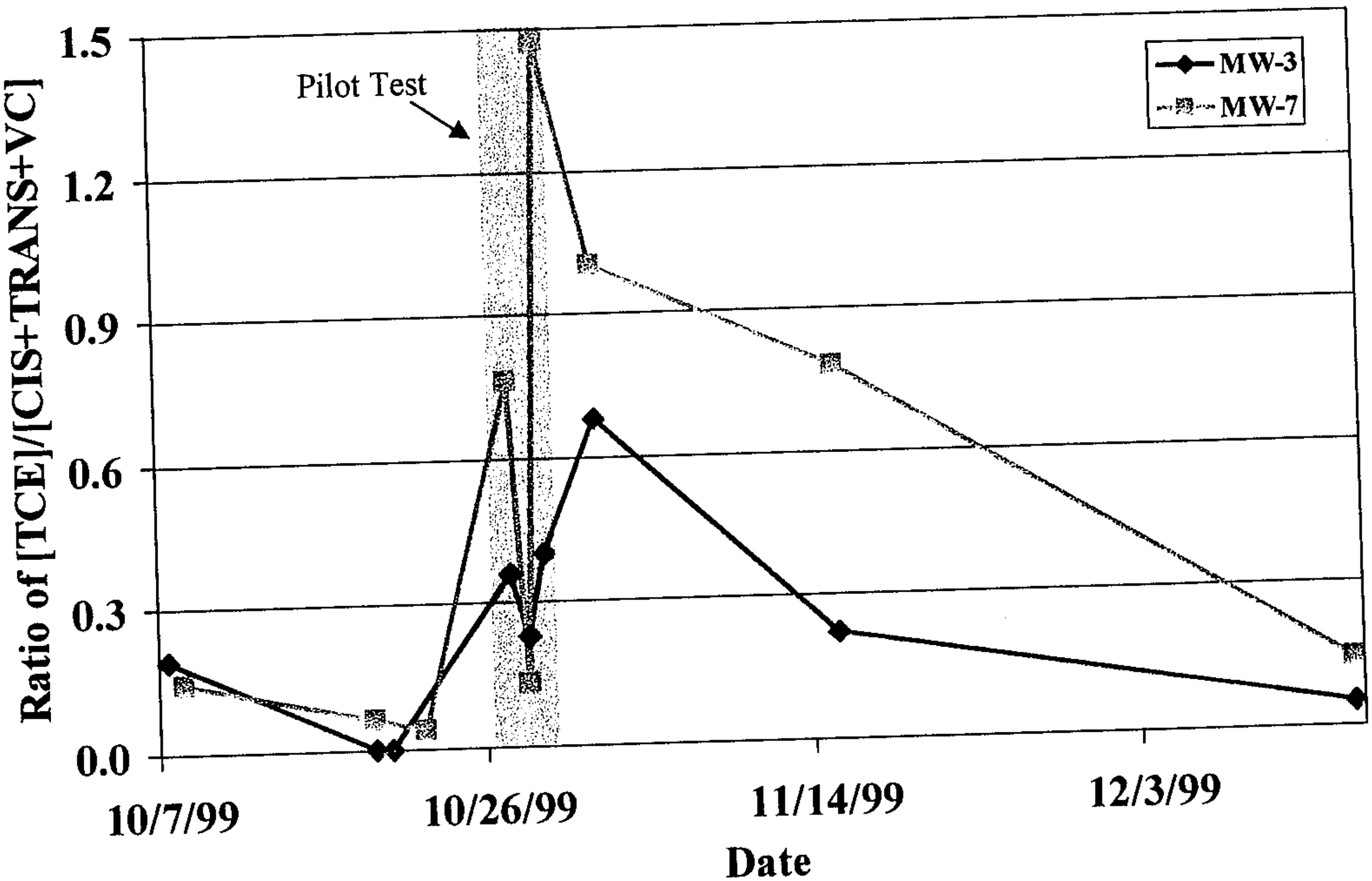


Figure 12. Concentration Ratio of TCE to Breakdown Products



APPENDIX E

CALCULATIONS

Objective: Calculate zero order reaction rate constant for hydrogen test

Zero order rate constant $K = \frac{\text{mass } H_2 \text{ consumed}}{(\text{injection volume} \times \text{mean residence time})}$

mass consumed = initial mass injected - mass recovered - diffusion loss

initial mass = (volume injected)(initial concentration)

Volume injected = 42 gallons = 159 L

initial concentration 0.232 mg/L

Initial mass = (159 L)(0.232 mg/L) = 36.9 mg

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2

By CC Date ______ Subject Reaction Rate Sheet No. 2 of 9

Chkd. By ______ Date ______ Proj. No. 781791

.25 in. X .25 in.

mass H_2 recovered - Calculated by integration below curve of concentration vs. volume recovered. Used Numerical method

Area between two points estimated as a rectangle and triangle.

$$Area = (x_j - x_i) * \min(y_i, y_j) + 1/2 (x_j - x_i) * ABS(y_j - y_i)$$

See attached graph for illustration and attached table for results

Total Mass recovered = 1.24 mg

Diffussion Loss - based on SF_6 losses during the test period.

Loss SF_6 = Initial Mass − Recovered Mass

Recovered Mass calculated by integration below the curve as described above.

$M_{initial}$ = 2702 mg $M_{recovered}$ = 145.8 mg

$$\% \text{ recovery} = \frac{145.8}{2702} = 0.054$$

or 0.946 loss to diffussion

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3

By CCW Date ____ Subject Reaction Rate Sheet No. 3 of 9

Chkd. By ____ Date ____ Proj. No. 781791

.25 in. X .25 in.

Therefore mass H_2 consumed = Total loss - diffussion loss

Total loss = 36.9 mg − 1.24 = 35.66

Diffussion loss = (36.9)(0.946) = 34.91

∴ Mass Consumed = 35.66 mg − 34.91 mg = 0.75 mg

MW H_2 = 2 $\frac{0.75 \text{ mg}}{2}$ = 0.375 m Moles

Estimate the mean Residence Time - This is typically based on the time where one half of the tracer has been recovered. Because of the low recovery of tracer - this will have to be estimated

Total time

injected started	7:40 am	21-OCT-99
injection completed	11:30 am	21-OCT-99
started Recovery	8:07 am	22-OCT-99
Ended Recovery	16:39 pm	22-OCT-99

Total Time = 33 hrs = MAX Res. dence time

For Push Pull Last in = First out
min Res. dence time = 20.5 hrs

use avg (33 + 20.5)/2 = 26.75 hrs

(4)

$$\therefore \quad K \cong \frac{0.375 \text{ mMoles}}{(150)(26.75 \text{ hrs})} = \frac{0.000093 \text{ mMoles}}{L \text{ hr}}$$

This value is several orders of magnitude less than that reported by Smith, et al.

The hydrogen provides electrons for completion of the anaerobic degradation by the following reaction

$$H_2 + CO_2 \rightarrow CH_4 + H_2O$$

$\therefore$ We can assume 1 mMole H_2 consumed for each mMole Carbon

For example - Vinyl Chloride C_2H_3Cl

2 mMole carbon dioxide formed during the biodegradation process.

$$\therefore \quad K_{C_2H_3Cl} = \tfrac{1}{2} K_{H_2} = 0.000045 \text{ mMoles/L-hr}$$

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(5)

By ccw Date ______ Subject Reaction Rate Sheet No. 5 of 9

Chkd. By ______ Date ______ Proj. No. 781791

.25 in. X .25 in.

MW-3 pre H_2 test had 82 ug/L vinyl chloride.

$$\frac{82\,\mu g}{L}\left|\frac{1\,mg}{1{,}000\,\mu g}\right|\frac{1\,mMole}{62.5\,mg} = 0.00131\ mMoles/L$$

Calculate time to Vinyl Chloride conc < 2 ug/L (MCL)

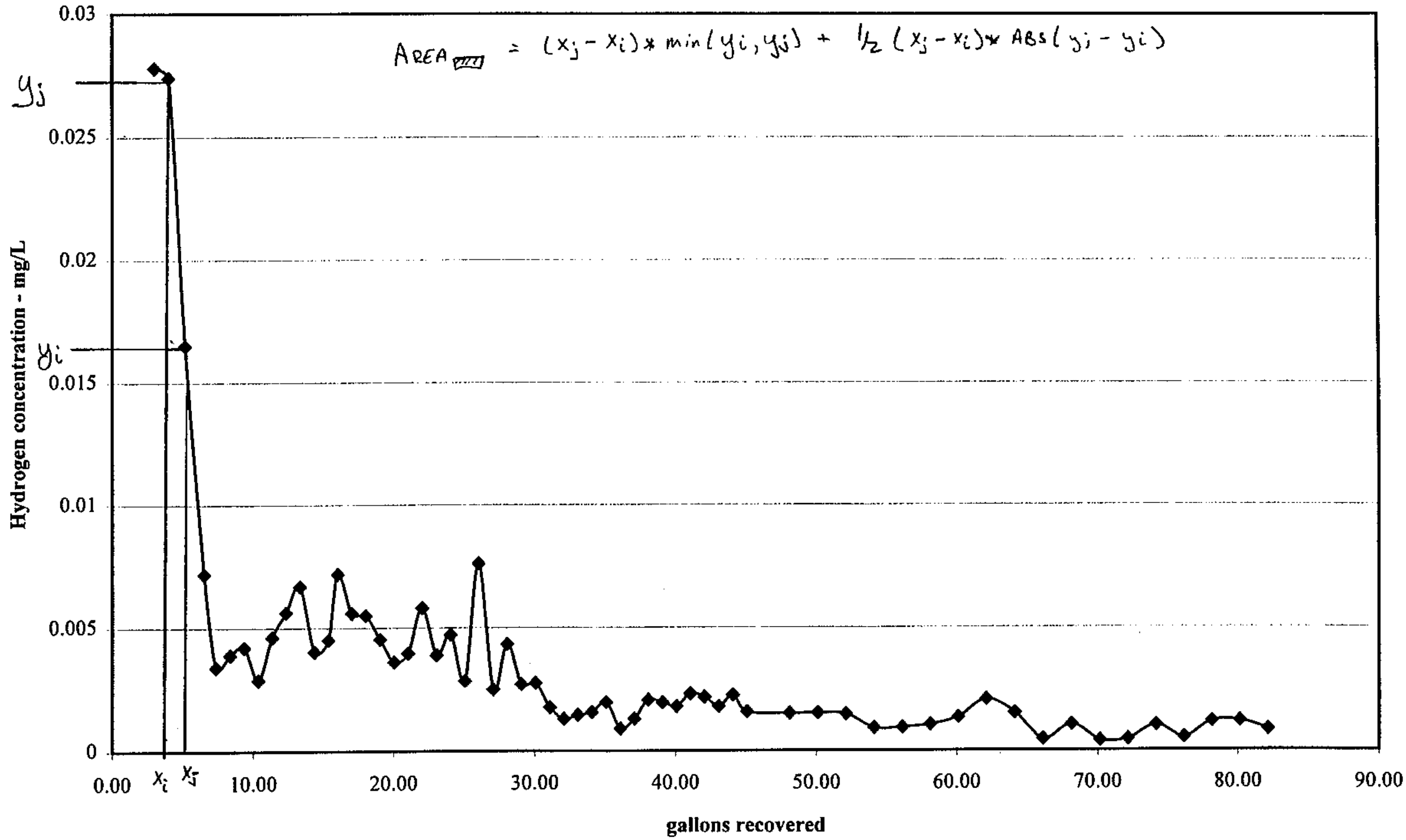
$2\,\mu g/L = 0.00003\ mMoles/L$

Reduction = 0.00131 − 0.00003 = 0.00128 mMoles/L

$$\frac{0.00128\ \frac{mMoles}{L}}{0.000044\ \frac{mMoles}{L\text{-}hr}} = 29\ hrs$$

E/9

Hydrogen Recovery



7/9

H2 Recovery Calculation

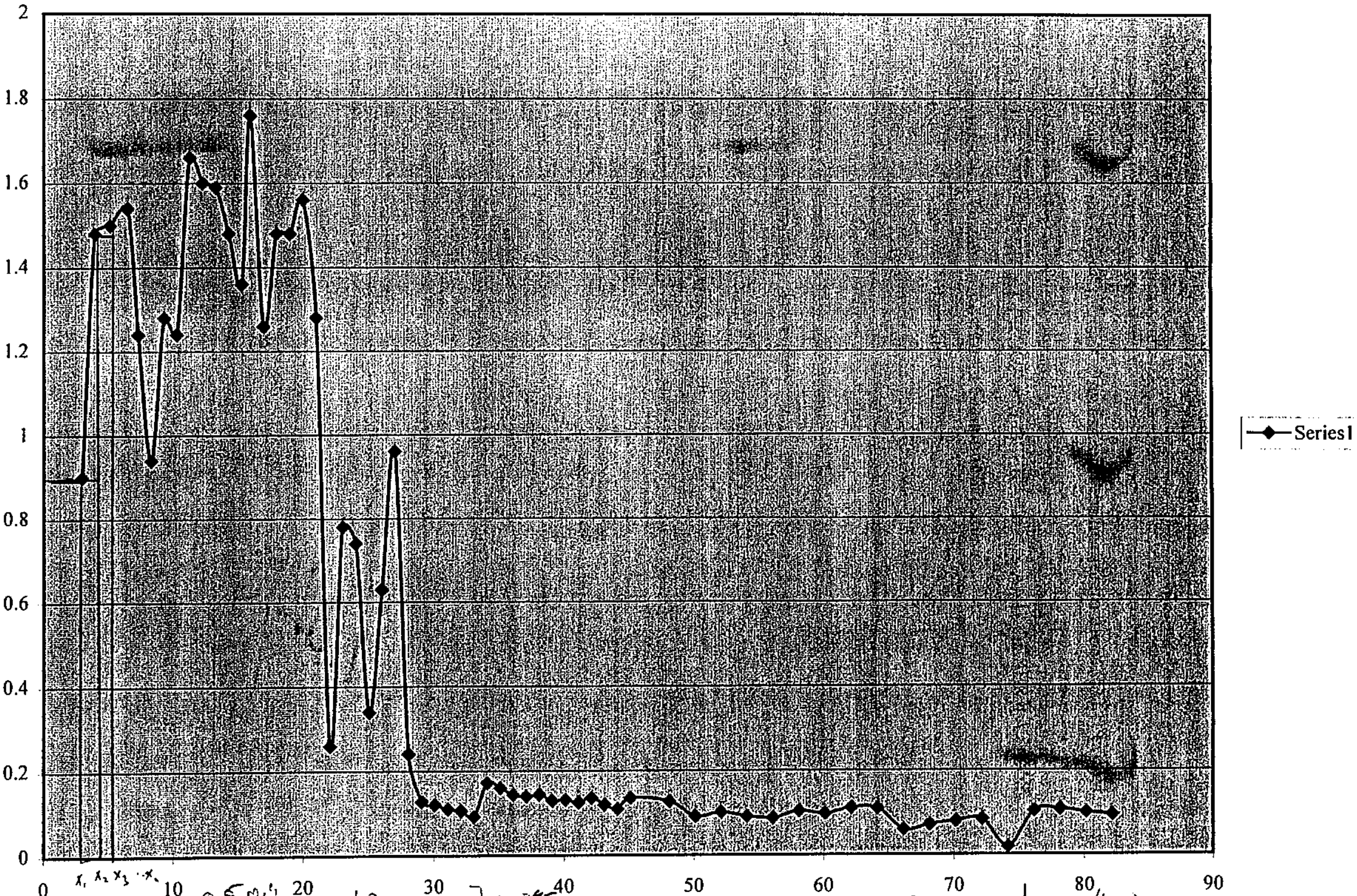
Volume pumped - gal	H2 mg/L	H2 Recoverd - mg
3.00	0.0278	0.32
4.00	0.0274	0.10
5.17	0.0165	0.10
6.51	0.00717	0.06
7.34	0.0034	0.02
8.34	0.00391	0.01
9.35	0.00421	0.02
10.35	0.00289	0.01
11.35	0.00463	0.01
12.35	0.00563	0.02
13.35	0.00668	0.02
14.36	0.00403	0.02
15.36	0.00451	0.02
16.03	0.00718	0.01
17.03	0.0056	0.02
18.03	0.0055	0.02
19.03	0.00453	0.02
20.03	0.00361	0.02
21.04	0.00397	0.01
22.04	0.00581	0.02
23.04	0.0039	0.02
24.04	0.00472	0.02
25.04	0.00285	0.01
26.05	0.0076	0.02
27.05	0.00251	0.02
28.05	0.00433	0.01
29.05	0.0027	0.01
30.05	0.00276	0.01
31.06	0.00176	0.01
32.06	0.0013	0.01
33.06	0.00145	0.01
34.06	0.00157	0.01
35.06	0.00196	0.01
36.07	0.000901	0.01
37.07	0.0013	0.00
38.07	0.00206	0.01
39.07	0.00195	0.01
40.07	0.0018	0.01
41.08	0.00231	0.01
42.08	0.00217	0.01
43.08	0.0018	0.01
44.08	0.00226	0.01
45.08	0.00158	0.01
48.09	0.00151	0.02
50.09	0.00153	0.01
52.10	0.00148	0.01
54.10	0.00092	0.01
56.11	0.000944	0.01
58.11	0.00105	0.01
60.11	0.00135	0.01
62.12	0.00208	0.01
64.12	0.00152	0.01
66.13	0.000463	0.01
68.13	0.00105	0.01
70.13	0.000407	0.01
72.14	0.00046	0.00
74.14	0.00102	0.01
76.15	0.000529	0.01
78.15	0.00118	0.01
80.15	0.00119	0.01
82.16	0.000844	0.01
		1.24

Injected volume	42 gallons
Initial Concentration	0.232 mg/L
Mass H2 Injected	36.88104 mg

$\frac{17 \text{ mg}}{L} \times 159L = 2,703$ mg SF_6 Injected

159L

SF_6 mg/L



$x_1\ x_2\ x_3 \cdots x_n$

$[\ \cdot\ * \ \cdot + 1/2(\cdot)*(0.58)] = .785$

Volume water Recovered (gallons)

AREA = $(x_2 - x_1) * y_1 + \frac{1}{2}(x_2 - x_1) * (y_2 - y_1)$

$\left(\frac{\text{gal} - \text{mg}}{L}\right)\left(\frac{3.785 L}{1 \text{ gal}}\right)$ ([illegible])

5/8

SF6 Recovery Calculation

Volume pumped - gal	SF6 mg/L	SF6 Recoverd - mg
	17	
3.00	0.90	10.22
4.00	1.48	4.51
5.17	1.50	6.59
6.51	1.54	7.69
7.34	1.24	4.39
8.34	0.94	4.13
9.35	1.28	4.21
10.35	1.24	4.78
11.35	1.66	5.50
12.35	1.60	6.18
13.35	1.59	6.05
14.36	1.48	5.82
15.36	1.36	5.39
16.03	1.76	3.94
17.03	1.26	5.73
18.03	1.48	5.20
19.03	1.48	5.61
20.03	1.56	5.76
21.04	1.28	5.39
22.04	0.26	2.92
23.04	0.78	1.97
24.04	0.74	2.88
25.04	0.34	2.05
26.05	0.63	1.84
27.05	0.96	3.02
28.05	0.24	2.28
29.05	0.13	0.70
30.05	0.12	0.47
31.06	0.11	0.44
32.06	0.11	0.41
33.06	0.09	0.38
34.06	0.17	0.50
35.06	0.16	0.63
36.07	0.14	0.58
37.07	0.14	0.54
38.07	0.14	0.54
39.07	0.13	0.52
40.07	0.13	0.50
41.08	0.13	0.49
42.08	0.14	0.50
43.08	0.12	0.49
44.08	0.11	0.44
45.08	0.14	0.47
48.09	0.13	1.50
50.09	0.09	0.83
52.10	0.10	0.74
54.10	0.09	0.74
56.11	0.09	0.68
58.11	0.10	0.73
60.11	0.10	0.77
62.12	0.11	0.80
64.12	0.11	0.84
66.13	0.06	0.64
68.13	0.07	0.50
70.13	0.08	0.58
72.14	0.08	0.62
74.14	0.02	0.39
76.15	0.10	0.46
78.15	0.11	0.80
80.15	0.10	0.79
82.16	0.09	0.74
		145.76

Injected volume	42 gallons
Initial Concentration	17 mg/L
Mass SF6 Injected	2702.49 mg

≈ 5% Recovery

Fraction Recovered → 0.05394 SF_6

Fraction Recovered 0.03364 H_2

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By CGN Date ______ Subject H_2 Test – Significance test for H_2 vs. SF6 Sheet No. ______ of ______

Chkd. By ______ Date ______ Proj. No. ______

.25 in. X .25 in.

Objective: Determine if ~~the~~ there is a significant difference between the hydrogen and sulfur hexafluoride recoveries.

method: using student's T test – determine is difference between the normalized concentrations are >0 or =0

~~the~~ null hypothesis $C_{H_2} - C_{SF_6} = 0$

students T

$$t = \frac{\bar{x} - \Delta}{s.d./\sqrt{n}}$$

$\bar{x}$ = average of values

Δ = difference comparing actual difference

s.d. Standard Deviation

n – number of data points

By CGN Date Subject H_2 Test - Significance test for H_2 vs SF_6 Recovery Sheet No. 2 of

Chkd. By Date Proj. No.

.25 in. X .25 in.

Data set is attached

For full data - considering the differences

~~#~~ null hypothesis - Delta = 0

full data set

$\bar{X} = 0.01681$
s.d. = 0.0308
$n = 61$
$t =$ ~~[illegible]~~ 4.2647

for $n > 25$ $\alpha = 0.005$ $t = 2.576$
Reject the null hypothesis
∴ Significant difference

H2	SF6	Delta
0.119828	0.052941	-0.066886
0.118103	0.087059	-0.031045
0.071121	0.088235	0.017115
0.030905	0.090588	0.059683
0.014655	0.072941	0.058286
0.016853	0.055294	0.038441
0.018147	0.075294	0.057148
0.012457	0.072941	0.060484
0.019957	0.097647	0.07769
0.024267	0.094118	0.06985
0.028793	0.093529	0.064736
0.017371	0.087059	0.069688
0.01944	0.08	0.06056
0.030948	0.103529	0.072581
0.024138	0.074118	0.04998
0.023707	0.087059	0.063352
0.019526	0.087059	0.067533
0.01556	0.091765	0.076204
0.017112	0.075294	0.058182
0.025043	0.015294	-0.009749
0.01681	0.045882	0.029072
0.020345	0.043529	0.023185
0.012284	0.02	0.007716
0.032759	0.037059	0.0043
0.010819	0.056471	0.045652
0.018664	0.014118	-0.004546
0.011638	0.007529	-0.004109
0.011897	0.007059	-0.004838
0.007586	0.006471	-0.001116
0.005603	0.006235	0.000632
0.00625	0.005412	-0.000838
0.006767	0.010118	0.00335
0.008448	0.009412	0.000963
0.003884	0.008471	0.004587
0.005603	0.008235	0.002632
0.008879	0.008471	-0.000409
0.008405	0.007647	-0.000758
0.007759	0.007765	6.09E-06
0.009957	0.007412	-0.002545
0.009353	0.008	-0.001353
0.007759	0.007059	-0.0007
0.009741	0.006471	-0.003271
0.00681	0.008	0.00119
0.006509	0.007529	0.001021
0.006595	0.005412	-0.001183
0.006379	0.006	-0.000379
0.003966	0.005412	0.001446
0.004069	0.005176	0.001108
0.004526	0.006118	0.001592
0.005819	0.005765	-5.43E-05
0.008966	0.006588	-0.002377
0.006552	0.006471	-8.11E-05
0.001996	0.003529	0.001534
0.004526	0.004235	-0.000291
0.001754	0.004706	0.002952
0.001983	0.004941	0.002958
0.004397	0.001059	-0.003338
0.00228	0.006118	0.003837
0.005086	0.006353	0.001267
0.005129	0.005882	0.000753
0.003638	0.005529	0.001891

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By CBW Date 6/25/98 Subject H_2 Test - Injection Volume Sheet No. ____ of ____

Chkd. By____ Date____ Proj. No. ____

.25 in. X .25 in.

Objective - Calculate Volume of water for injection for H_2 treatability study.

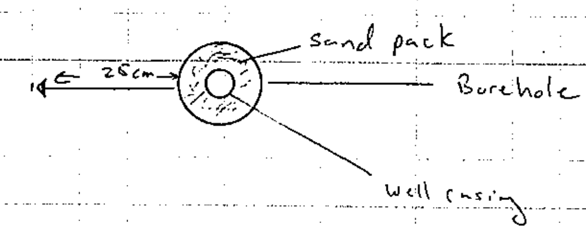
Basis: "Single Well "Push-Pull" Test for In-Situ Determination of Microbial Activities"
Istok, et. Al; Ground Water V 35 No 4 pp 619-631

Need Volume sufficient to penetrate a radial distance into the aquifer of 25 cm beyond the outer edge of the sand pack.

Well Construction Info

Borehole dia 6"
Well diameter 2"

Screened interval 8-13'



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By ______ Date ______ Subject ______ Sheet No. ______ of ______

Chkd. By ______ Date ______ Proj. No. ______

.25 in. X .25 in.

Assume porosity of sand and formation are $0.3 = \alpha$

total liquid volume

Volume in casing + Volume in sand pack + Volume in formation

casing volume $= \pi r_c^2 h$ $\quad r_c = \frac{1}{12} = 0.083'$, $h = 5'$

casing = 0.8 gallons

Sand pack volume $= [\pi r_{sp}^2 - \pi r_c^2] h\alpha =$ $\quad r_{sp} = 0.25'$

$= [\pi (0.25)^2 - \pi (0.083)^2](5)(0.3) = 0.262 \text{ ft}^3$

sand pack = 1.96 gallons

Formation $= \{\pi r_f^2 - \pi r_{sp}^2\} h \alpha$ $\quad r_f = 9.8 + 3 = 12.8 = 1.1'$, $r_{sp} = 3 = 0.25'$

$\{\pi (1.1)^2 - \pi (0.25)^2\}(5)(0.3) = 5.4 \text{ ft}^3$

40 gallons

Pump $0.8 + 1.96 + 40$ gallons out $= 42.76$ gallons

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By CGN Date ______ Subject Calculate initial Radius of influence of 80 gal $KMnO_4$ injection Sheet No. 1 of 1

Chkd. By ______ Date ______ Proj. No. ______

.25 in. X .25 in.

Objective: Estimate radius of influence of 2% $KMnO_4$ injection.

Volume injected	~~2%~~ 80 gallons = 10.7 ft^3
Injection interval	2 ft
Soil porosity – ϵ	30%

pore volume in column of soil = $\pi r^2 h (\epsilon)$

Total volume injected = 10.7 ft^3

$$10.7 \text{ ft}^3 = \pi r^2 h \epsilon$$

Solve for r

$$\left(\frac{10.7}{\pi h \epsilon}\right)^{1/2} = r$$

$$\left[\frac{10.7}{(\pi)(2)(0.3)}\right]^{1/2} = r$$

$$2.4' = r$$

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FIELD ACTIVITY DAILY LOG

DAILY LOG			
DATE			
NO.			
SHEET 1	OF 2		

PROJECT NAME: WPAFB	PROJECT NO.:
FIELD ACTIVITY SUBJECT: $KMnO_4$ Solution Requirements – Calculation	

DESCRIPTION OF DAILY ACTIVITIES AND EVENTS:

Objective: Calculate volume of 2% $KMnO_4$ solution needed at FAA-B

Experimental Result ⇒ Soil Oxidant Test

9 mL 5% $KMnO_4$ needed for each 40 grams soil

9 mL ≈ 9 gr total

$(9)(0.05) = 0.45$ gr $KMnO_4$ / 40 grams soil

$$\frac{0.0113 \text{ parts } KMnO_4}{1 \text{ part Soil}}$$

Calculate volume of soil to be treated at each injection point ~~Treat~~

Treatment radius 15'
Treatment depth 5'

VISITORS ON SITE:

CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS:

WEATHER CONDITIONS:

IMPORTANT TELEPHONE CALLS:

IT PERSONNEL ON SITE:

SIGNATURE: DATE:

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FIELD ACTIVITY DAILY LOG

DAILY LOG			
DATE			
NO.			
SHEET 2 OF 2			

PROJECT NAME: WPAFB | PROJECT NO.:

FIELD ACTIVITY SUBJECT: $KMnO_4$ Solution Requirements – Calculation

DESCRIPTION OF DAILY ACTIVITIES AND EVENTS:

Soil Volume $= \pi (15)^2 5 = 3,534\ ft^3$ say $3,500\ ft^3$

soil density $1.5\ gr/ml \approx 93.5\ lb/ft^3$

Total wgt soil treated

$(3,500)(93.5) = 327,285$ lbs soil

determine total lbs $KMnO_4$

$$\left(\frac{0.0113 \text{ lbs } KMnO_4}{1 \text{ lb soil}}\right)\left(327,285 \text{ lbs soil}\right) = 3,698 \text{ lbs } KMnO_4$$

Calculate volume 2% Solution

$$\frac{3,698 \text{ lbs } KMnO_4}{X \text{ lbs Solution}} = 0.02$$

$X = 184,900$

Say 8.34 lbs/gallon = 22,170 gallons total

Say 22,000 gallons

VISITORS ON SITE:

CHANGES FROM PLANS AND SPECIFICATIONS, AND OTHER SPECIAL ORDERS AND IMPORTANT DECISIONS:

WEATHER CONDITIONS:

IMPORTANT TELEPHONE CALLS:

IT PERSONNEL ON SITE:

SIGNATURE: DATE: